

CESI

CESI Sourcebook V - Third Edition

PHYSICAL SCIENCE ACTIVITIES FOR ELEMENTARY AND MIDDLE SCHOOL



Edited, Compiled, and Produced by
Mark R. Malone

PHYSICAL SCIENCE ACTIVITIES FOR ELEMENTARY AND MIDDLE SCHOOL

CESI SOURCEBOOK V

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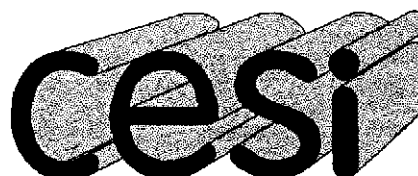
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Dedicated to my best friend, Sue.

Preface

For over seventy-five years the Council for Elementary Science International (*CESI*) has been dedicated to improving the quality of preschool through middle school science education. The association participates in a variety of activities designed to stimulate, improve, and coordinate science teaching. Since 1979, *CESI* Sourcebooks have proved to be an ideal means of reaching classroom teachers with creative ideas to utilize in their day to day work with students. No other book published by *CESI* has been as well received as *Physical Science Activities for Elementary and Middle School*.

This fifth Sourcebook continues the tradition of quality science material presented in a quick reference format, for use by classroom teachers. It contains materials developed for teachers by teachers who have tested them with their own students. Practical and creative ideas are always uppermost in *CESI* Sourcebooks. The association has always kept with a simple philosophy that the best ideas are those that involve "hands-on" activities with materials found locally and inexpensively. In an attempt to keep costs within reach of all classroom teachers, *CESI* offers its publications only through direct sales rather than through for profit publishers.

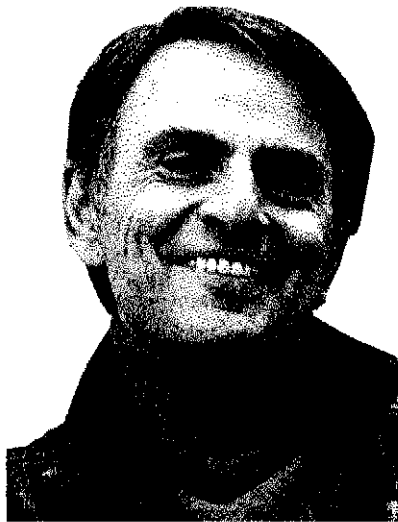
The quality of a Sourcebook is determined by the project editor. Mark Malone has selected the topics, contacted authors, edited, written activities, created graphics, formatted, and worked to produce this final product. This process has spanned many years. The first edition, published in 1987, required two years of work to produce. Dr. Malone has worked nearly another two years to produce the second and third editions of *Physical Science Activities for Elementary and Middle School*. The latest edition represents a major revision and improvement of this popular work.

Mark Malone is a professor of science education at the University of Colorado. He resides in Colorado Springs with his wife Sue and his two children Emmett and Cullen. He is a *CESI* board member and past president of *CESI*. He has also produced *CESI File Sheets* Volume 2, revised several other *CESI* publications, and is currently the Editor of *CESI Science™*. He is actively involved other research and teacher training programs including the recent PAIRS Project for which he was awarded the 1994 NSTA Star Award. *CESI* would like to thank him for his dedication to this project and improving science education through his many educational activities.



CHAPTER - I

INTRODUCTION



"Science is a way of thinking much more than it is a body of knowledge. Its goal is to find out how the world works, to seek regularities there may be, to penetrate to the connections of things..."

Carl Sagan

AN OUNCE OF PREVENTION

by Mark R. Malone

Every effort has been made in compiling this sourcebook to assure that all activities are academically sound, motivating and interesting for students, and reasonably safe for supervised student use. The ultimate responsibility for assuring that all of these goals are successfully met is the responsibility of the classroom teacher. As this book was compiled, close attention was paid to the safety aspects of the activities. Some activities were rejected due to safety concerns. Safety tips were added to others. In the end, however, it is the teacher's responsibility to assure that students are kept safe in conducting these activities and investigations.

Please pay careful attention to any safety tips included in activities. Unfortunately, it is not possible to predict all of the ways that these materials might be misused or malfunction in the hands of students. Just the fact that your students are doing some type of manipulative activity rather than sitting and reading a science text puts them at somewhat greater risk of injury.

All of these activities are designed to be done under adult supervision. Students should be reminded of this if they intend to repeat or extend any of these activities at home.

Precautions should be taken any time sharp objects, glassware, flame, chemicals, or other potentially hazardous materials are in use. When using chemicals (household or commercial), label directions should be read and carefully followed regarding safe use and poisoning. These label directions for safe use take precedence over any instructions stated or implied by this sourcebook. Properly store chemicals only in their original containers so that these directions are available in the event of an accident. It is hoped that these words of caution will help in preventing any unnecessary accidents.

WHAT IS THIS SOURCEBOOK ABOUT?

by Mark R. Malone

In the Spring 1986 meeting of the CESI Board of Directors, it was agreed that CESI should produce a fifth in a series of practical sourcebooks for teachers. The board decided that elementary science could presently benefit most from a sourcebook focused on physical science activities. Since that time this book has become the best selling CESI

Sourcebook ever. In 1992 the board requested that this Sourcebook be updated and revised. Hopefully this second edition of the sourcebook will be as well received as the first edition.

This sourcebook was developed mainly for use with elementary and middle school students, although many activities could be easily adapted for use with older students. Like the previous sourcebooks, *Physical Science Activities for Elementary and Middle School* emphasizes teaching science through activities. Mounting research evidence shows that an activity centered approach to elementary and middle school science education is quite effective. A synthesis study (Shymansky, Kyle, and Alport, 1983) involving over 45,000 students showed that students involved in activity oriented science programs performed better than 62 percent of students in non-activity science programs in general achievement, analytic skills, process skills, and related skills (reading, mathematics, social studies and communication). A related study (Bredderman, 1983) showed similar results with the activity approach in 1000 elementary classrooms on measures of science processes, creativity, attitudes, perceptions, and logical development. In addition, Bredderman found, through an analysis of classroom observation, that activity oriented classes resulted in decreased teacher talk and lecturing, increased use of higher level questioning, and more active engagement of students.

Currently, most elementary science textbook series offer "integrated" equipment and material kits. In every case the manipulative materials are available as an option. Because of limited budgets, many schools now purchase the textbooks but cannot afford to buy the supplementary kits. As a result many elementary and middle school students still grow up thinking science is merely something else to read (Thier, 1986).

Sourcebook V, like its predecessors, presents many activity oriented science lessons that can be done in any elementary or middle school classroom with minimal additional expense. Nearly all lessons utilize materials that can be easily found around the school and home or that can be purchased inexpensively from local sources (grocery stores, hardware stores, department stores, etc.). Like previous sourcebooks, it should be a valuable resource for many classroom teachers.

Physical Science Activities for Elementary and Middle School is the fifth sourcebook of the Council for Elementary Science International. The other five are

Outdoor Areas as Learning Laboratories, compiled and edited by Alan J. McCormack; *Expanding Childrens' Thinking Through Science*, compiled and edited by Michael R. Cohen and Larry Flick; *Understanding the Healthy Body*, compiled and edited by David R. Stronck; *Science Experiences for Preschoolers*, compiled and edited by Leon Ukens; and *Water, Stones, & Fossil Bones*, compiled and edited by Karen Lind. All of these sourcebooks have a similar format for the activities and emphasize inexpensive, easily obtained materials and equipment.

The format for the activities is as follows:

Title of Activity: We have tried to invent titles that reflect both the fun of the activity and its learning focus. In many instances, our hope is that the title itself will pique young students' natural curiosity.

Focus: This is a short description of the concepts and/or skills developed by the activity. It also provides a quick capsulation of the activity to assist readers in rapidly understanding what the activity is all about.

Challenge: Using a challenge or problem-oriented approach to activities is one good way to stimulate student interest.

Materials and Equipment: A list of everything needed is provided with each activity. Feel free to vary the amounts of the materials to meet the needs of any class size. Construction suggestions are often provided for homemade apparatus. Hopefully, you will be able to find all materials at little or no cost.

Procedure: These are suggestions for planning, organizing, and actually implementing the activities with students. These are teacher-tested methods that have worked well for the contributing authors. But, feel free to invent your own variations.

Further Challenges: One solved challenge always leads to new challenges and those, in turn, lead to new learning opportunities. This section includes a few ideas for related, but different, learning activities. These challenges are entirely open-ended, and solutions are left to the students and teachers.

References: Articles and books are identified to give both teachers and students useful information related to this activity.

References:

Bredderman, T. (1983). "Effects of Activity-Based Elementary Science on Student Outcomes: A Quantitative Synthesis", *Review of Educational Research*, 53: 499-518.

Shymansky, J., W. Kyle, Jr. and J. Alport. (1983) "The Effects of New Science Curricula on Student Performance", *Journal of Research in Science Teaching*, 20: 387-404.

Thier, H. D. (1986). *"Hands on Elementar Science The Challenge for the Nineties"*, Monograph and Occasional Paper Series, Washington, DC.: Council for Elementary Science International.

LEARNING CYCLE FOR PHYSICAL SCIENCE

by Mark R. Malone

With any science activity, the materials used are not as critical as the methods used in communicating ideas to students. Physical science activities included in this sourcebook lend themselves quite well to inquiry oriented strategies. One of the advantages of physical science activities is that they generally can be conducted in a short time frame. This characteristic of physical science activities allows students to see many phenomena associated with an apparatus or event in a short period of time. This is in contrast to other areas of science study, such as biological phenomena, that take several days, weeks, or months to observe and are often difficult to repeat if something goes wrong. The immediacy of results allows students to gather data under controlled circumstances, repeat observations, and correct immediately for procedural problems resulting in faulty data.

Learning cycle is a method of daily classroom instruction that allows students to explore in an inquiry fashion yet retains enough structure in lesson so that a teacher can still feel in control of the teaching situation. It represents a significant compromise between the "free-form," "self-directed" inquiry methods promoted by some in the 1960's and "direct instruction" methods which were promoted in the 1980's. The learning cycle can allow you to take full advantage of the nature of physical science activities presented in this sourcebook.

Learning cycle, as presented here, incorporates and builds upon a general scheme of instruction developed by Karplus and Thier (1967). It is also sometimes identified as the

SCIS Learning Cycle because its initial and most well known use was with the Science Curriculum Improvement Study (SCIS) developed by Karplus, Thier and others working at the Lawrence Hall of Science under a federal grant. The wide acceptance of this learning cycle is attested to by the fact that it is cited and described in nearly all college science methods textbooks for elementary teachers and in many contemporary books dealing with general elementary school curriculum. The learning cycle's purpose is to develop learning situations through which students can gain science concepts in such a way that they can interpret information as if they had obtained it themselves. Though this is a laboratory approach to learning, students are not expected to discover all concepts for themselves. The general scheme of instruction includes a three-phase sequence of **exploration**, **invention**, and **expansion** (originally referred to as discovery).

During the initial *exploration* phase, students are presented with materials or arrangements of materials which are unfamiliar to them. They must sort, identify, and label properties and characteristics of these materials. Aspects of the materials that are already familiar to them serve as a catalyst for organizing the learners' ideas about the materials. This phase is a period of free exploration or play with the materials. It gives the children in a classroom setting an opportunity to be "children." They can explore freely and discover what they can on their own. It is a process that is very respectful of children "as children" rather than as "miniature adults." During this phase of inquiry the teacher must refrain from telling students why something has happened. They should concentrate on questions that focus students on what is happening or how a phenomenon occurs. This phase serves several purposes. It gives children an opportunity to do what they would do with the same materials in a non-school setting. They will choose to learn about what is most interesting and appropriate for them at the time. This exploration period provides common experiences from which all students can draw during the more directed phases that follow. This phase of the learning cycle also tends to diminish discipline problems for the teacher. Because playing, within guidelines of safety, is allowed and encouraged, students are more likely to be attentive and cooperative in the more structured tasks that follow.

This is in contrast to what might occur in a very directive laboratory approach. For example, picture an eight-year-old child, given a magnifying glass and a twig, being told to look at the buds on the twig and identify the parts. In

this situation the magnifying glass itself is likely far more interesting than the twig. The student is expected to ignore all of the interesting characteristics of the glass, such as its ability to turn the whole world upside-down, to enlarge another student's eye, or to focus a concentrated circle of light on the twig to sear its bark. In a very directed lab situation the student is likely to get in trouble for any one of the above other than looking at the bud on the twig. The learning cycle assumes that the twig and the magnifying glass may be equally interesting and educational depending on the student's past experience. After the child has had an opportunity to explore the magnifying glass, he is much more likely to be able to focus later on a more structured look at the twig.

Exploration has set the stage for the next phase of inquiry, *Invention*. This phase helps students to organize experiences from their exploration. With the teacher's guidance, students group their experiences into descriptions, explanations, classifications, or hypotheses. This phase is the most teacher directed of the three phases. It usually takes place in the context of a full group discussion. The teacher and students cooperatively "invent" names for concepts or phenomena described by students, based on their observations. The teacher also prompts students to plan to conduct more systematic investigation of the materials being explored. The teacher and students cooperatively devise a plan for further, usually systematic, study of the materials. During the *Invention* phase procedures such as drill, reading, and passive listening to teacher lecture are inappropriate. Appropriate activities include further display or manipulation of the materials, discussion, directive questioning techniques, and organization of a plan for further study. Potential future learning lies within the inventions themselves as a basis for the *Expansion* phase which follows.

Expansion I is the testing of an invention's adequacy. Does the invention account for various arrangements, actions, or events with the materials, or for new objects under similar conditions? This phase is generally characterized by students conducting some type of controlled investigation or systematic observation. This process serves to strengthen, establish, modify, or destroy inventions. The teacher's role during this phase is to guide students to investigate the strengths, logic, and integrity of inventions through manipulative experiences. By this phase of learning cycle, various manipulative experiences have provided the student with a cognitive structure for understanding the concepts.

Further expansion of the concept can take place in *Expansion II*, using more formal information presenting techniques such as assigned readings, writing, discussion, and lecture. These activities are appropriate at this time because students have developed a meaningful cognitive structure for dealing with material in a more abstract manner. This sub-phase of expansion will be referred to as *Expansion II*. This phase was alluded to, though not labeled as "*Expansion II*," in the early writings of Karplus and Thier. It was not, however, included as a dominant part of the SCIS program's applications of learning cycle procedures. If one of your goals of instruction is to enable students to read written material related to physical science concepts taught, *Expansion II* is the most appropriate placement for this type of instruction. Any type of age appropriate reading related to the concepts developed in the lessons will aid students in fully understanding these concepts. You are encouraged to locate appropriate readings from current journals, magazines, or textbooks that enhance students' understanding of these physical science concepts. To be true to the learning cycle, these readings must be placed in the sequence of the lesson after, not before, the manipulative experience portion of a lesson.

The *Expansion II* phase of the learning cycle allows you to expand childrens' understanding of science concepts through inclusion of other contemporary goals of science instruction. Through formal teaching strategies such as reading, discussion, or brief lectures, students can learn how the science concepts or skills from earlier phases of the learning cycle fit into a larger scheme of understanding. Potential careers in science related to a topic studied can be explored. Real world examples of applications of a concept become more meaningful. Students can engage in meaningful discussions pertaining to how information learned can assist them in becoming responsible citizens. Personal utility of information or skills studied can be explored. This new phase of the learning cycle can also aid students in seeing how academic information or skills learned in the current lesson may apply to future study. It also provides teachers with a mechanism for bringing closure to a lesson.

Many activities presented in this sourcebook can be greatly enriched when implemented with learning cycle strategies. It should be kept in mind, however, that many other teaching strategies can also be used effectively for presenting these activities to children. Learning cycle should be viewed as one of many tools appropriate for designing good instruction for elementary and middle

school. Varying your approach to instruction from time to time will help to motivate and hold the interest of your students.

Reference:

Karplus, R. & H.D. Thier. (1967) *A New Look at Elementary School Science - Science Curriculum Improvement Study*, Chicago, IL: Rand McNally & Company.

SELECTING SCIENCE PROCESS ACTIVITIES

by G. Wm. Foster

Process science requires a variety of teaching skills and behaviors ranging from keeping track of materials to asking appropriate questions. Not only does a teacher have to contend with children using the materials correctly but also with the fear that the activity may not go as planned. That is, how will children react to the activity? Will they be bored or interested? Will they hurry through it or will they take their time? Developing a systematic analysis of science activities can allay fears of the unknown. It also helps to have a clear understanding of why process science needs to be a part of the elementary curriculum. With this understanding, many of the common problems associated with hands-on activities will no longer be considered problems but situations with positive outcomes.

First of all, the reader must keep in mind that the primary reason for hands-on science activities in the classroom rather than the traditional textbook centered approach, is that science itself is an activity. The second reason is that most science investigations require students to use mental operations that are important to intellectual development. Data are collected by observing, classifying, analyzing, predicting, hypothesizing, etc. How data are collected and conclusions reached varies greatly from one individual to another. Thus, science calls upon each individual to use a variety of critical thinking skills. Elementary and middle school children are at an age when critical thinking skills are developing. It is important that they can have the opportunity to abstract basic science concepts from concrete hands-on experience.

Science activities that nurture critical thinking skills and reflect the processes of science can be identified. The characteristics of science activities that help develop critical thinking skills are outlined below:

1. These activities include objects that have inherent observable relationships. Children can explore these relationships by their physical actions upon the objects. That is, children find these relationships without the aid of an adult or a list of procedures. For example, in "Pitch Paradox" a student can observe a direct relationship between the change of pitch and changes made on the pop bottles.

2. These activities include an assortment of objects to explore natural phenomena with a variety of observable relationships. For example, in "Electric Circles" students can explore circuits using a variety of types of batteries, bulbs, and wires that will give them a variety of relationships between variables such as bulb intensity, short circuits, parallel and series circuits.

3. Children can enter these activities at their own level of understanding. For example, "Closed Systems" allows a child who has never had experience with density of liquids to make a "diver" while on the other hand a child who has had experience with a "diver" can explore the effects of different liquids upon the "diver."

4. These activities have a variety of extensions to compensate for different levels of critical thinking skills and creativity. As you will notice, all of the activities in this book have extensions (usually labeled "Further Challenges"), which allow for different ability levels and act as motivators to keep the child interested in the activity.

5. These activities deal with scientific phenomena that appeal to a child's curiosity. For example, magnetism is a scientific phenomenon that children can easily explore and find fascinating at the same time.

6. These activities have relevancy to the child. Again taking magnetism as an example, magnets are found in toys, appliances, tools, etc. This scientific phenomenon is an excellent example of illustrating the relationship of science, technology, and their effects upon society.

Analyzing elementary science activities according to these criteria would give evidence that more physical science activities fit the criteria than do the biological science activities. In most biological science activities, a child cannot act directly upon the living objects without doing some harm to them. To properly explore living systems, most experiments call upon the investigator to change the environment of the living organisms. The effects of the

changes may be slow and hardly observable. Finally, the complexity of the variables associated with living things often makes it frustrating for children to sort out the changes that occur or don't occur to the living organisms. Thus, a student may lose interest before the changes occur or may lose interest because the science concepts are too abstract. By emphasizing physical science activities, many of the natural scientific phenomena found in living organisms can be better understood by children. For example, observing capillary action in straws, paper towels, and capillary tubes can pave the way to understanding the flow of sap in trees.

However, no matter whether the activity involves a biological or a physical concept, a teacher can ask several questions to determine whether the activity is appropriate to the student:

1. Does the activity allow for different levels of critical thinking skills?
2. Does the activity include objects so that relationships are clearly observable to the student?
3. How is the activity presented? Does it allow freedom of exploration, within the given classroom rules, or does it contain numerous directions that stifle children's natural curiosity?
4. As a teacher, do I spend my time giving and explaining directions or am I a facilitator of learning?

Most science activities can be adapted so that students find them rewarding and teachers find themselves facilitators of learning rather than directors of procedures and disciplinarians. In addition to adapting or finding activities that nurture critical thinking skills, a teacher can also do the following to help facilitate learning:

1. There is no such thing as a foolproof science activity. Crickets will die, bulbs burn out, chemicals will not react, etc. When things do not go according to plan, use the experience to find out what happened. It could lead to new and exciting understandings and discoveries for both student and teacher. Most breakthrough discoveries in science were made when things didn't proceed as expected.
2. Accept the variety of answers and questions you may receive from children. Each child may have a different understanding of the same scientific concept. Processing

information is more important than memorizing information.

3. Explore with the children. This helps model the type of learning that is expected in hands-on science classrooms.

4. Accept inquiry as part of teaching. Ask questions to find out what the child is thinking rather than "fishing" for particular answers. Use questions as an assessment tool. What does Johnny know about calories? Why are the children restless? How can I adapt the activity to their level of understanding? Why didn't the activity work?

To make science teaching successful in your classroom, you must become a facilitator through questioning, a motivator through ideas, and an advocate through listening to children. Science can be exciting and fun if both teacher and students explore the frontiers of the mind.

MAKING GOOD SCIENCE PROGRAMS EVEN BETTER

by Joan Tephly

If you are reading this book, you are interested in extending your science curriculum. While this sourcebook is filled with many excellent ideas you may want to incorporate, there are also some broader guidelines to apply to science programs.

Since 1982, the National Science Teachers Association has yearly drawn up criteria for excellence in different areas of science education. National searches have been conducted to find programs best matching the criteria (The Search for Excellence in Science Education). Since that time there have been several surveys of elementary, middle, and secondary education as well as physical science education.

The criteria used in the NSTA search are worth considering as yardsticks for your science program. They have been carefully developed by committees of experts in the varied aspects of science education. The following is a condensation of the primary criteria.

☐ The criteria always stress the need for students to be actively involved in their learning. This ranges from identification of science problems or questions to solution-seeking techniques, formulation of conclusions and interpretation of information. Programs should include concrete, hands-on experiences, exposure to inquiry and

problem-solving skills, and the opportunity to actually do some research.

☐ The science program should integrate with other areas of the school curriculum and other science disciplines, thereby aiding students in understanding and appreciating the technological and everyday applications of science. In striving to do this, the larger community must be part of the science program as curriculum resources, as representations of applied science, as sites for field trips, and as individuals who can serve as role models of science and science related careers. These role models provide early exploration of possible career choices and as such they should represent a range of sex, socioeconomic and ethnic exposures.

☐ Exemplary programs strive to move beyond the textbook and identify and study real-world problems. In so doing, students are exposed to topics of immediate and future concern in the larger environment. Students will learn to apply science knowledge as effective consumers, as individuals striving for effective personal health practices, as citizens making thoughtful decisions concerning their country and their planet.

☐ Students, even young students, should begin to develop an understanding of the means by which scientific knowledge is generated and scientific models and theories developed. What science is and what it is not, what it can do and what it cannot do are critical understandings about the nature of science.

☐ The backgrounds, abilities and interests of students must be considered in planning a science program. A variety of instructional content, strategies, and resources creates an interesting and individualized program.

☐ To teach science and do a good job, adequate time and materials are a necessity. They are not always present in an educational system's basic structure. They are goals worth struggling for.

In case these condensed criteria for really good programs sound overwhelming, a look at some of the characteristics of teachers who have created programs recognized as exemplary may stimulate you further.

Programs always reflect their creators. Exemplary programs were almost always developed because the teachers perceived a need among their students which was not being met by the curriculum in use. Usually a team of two or more teachers were the innovators, although

exceptional single teachers have been found. A leader existed within the team and most often the efforts were with administrative support. The new programs evolved with carefully designed goals and were implemented over a sustained time period. Linkages were established with higher education through continued coursework on the part of the innovators, and consultation and assessment support from college or university personnel. These new programs are never "in place". Even programs receiving national recognition as exemplary are constantly striving for improvement. Anyone striving to make curriculum changes can learn some pointers from these teachers.

- ☐ There is greater strength and wisdom in numbers (teams of two or more). Try to find others to build with.
- ☐ Administrative support, even involvement, is so important a teaming, trusting, respectful relationship. Strive to nurture it. Don't give up easily. Teachers dedicated to improvement do generate support.
- ☐ Consider networking with institutions of higher learning for support and expanded expertise. Personnel at such institutions can also provide the rationale you need to justify your desired changes.
- ☐ Value sustained inservice opportunities (release time, visiting, courses, workshops, professional meetings). Avoid burnout through the stimulation of new ideas. Appreciate that growth and change are slow and sustained.
- ☐ Think creatively, both to address your program needs and to expand into your community. Community support impresses administrators.
- ☐ Don't try to change your program too fast. You'll risk burnout.
- ☐ Never think your program has arrived. You'll risk stagnation.

YOU CAN TEACH SCIENCE ALL DAY LONG

by Joan Tephly

Ask any elementary teacher what curriculum area receives the greatest time emphasis during the school day and you will be told "Reading". Ask next what curriculum area most likely receives the least time in the daily schedule and

you will be told "Science". And with rare exception, the imbalance is greatest in the lower elementary grades. As an educator, you probably know this. But have you struggled with ways to do something about it?

Science can lend itself well to instruction all day long. It is easily integrated with other curriculum areas. Start with reading. Unfortunately, too many classrooms spend too much time reading during the brief amount of time allotted to science. But what about the large block of reading time? Can you teach science there? And can you justify teaching science during reading?

Reading and science build upon many of the same basic skills. This alone establishes a strong case for science during reading. Many of the skills used in the scientific method of investigation are also necessary in reading, such as observing, identifying and labeling, classifying and sequencing, describing, asking questions, seeking and recognizing relationships, gathering information, drawing conclusions, and communicating or reporting. They share much in common.

Topics and concepts under study in the regular science curriculum can be incorporated into reading time as learning center activities. These can be explored by children who finish reading assignments early and are not working directly with the teacher. The vocabulary or reading content associated with the science activity can also have some reading skill assignments attached to it; for example, find all the science vocabulary words with long vowels, or find the compound sentences in the reading materials. Vocabulary from the regular science curriculum can also be used as reading vocabulary from which language experience type activities can be built. If appropriate, this same vocabulary can become meaningful spelling words. Teachers will need to do this particular match of reading skills and science content for their own classroom of children.

Mathematics receives the second largest block of time in the school day. How easy it is to integrate the science and math time. Mathematical calculations need application to real problems. Scientific exploration demands record keeping, calculation, and problem solving.

Other language arts areas (listening, writing, oral communication, literature) all effectively build on science content. Oral speaking and expression as well as creative writing can be based on a topic of choice, and why not a science related topic? A science topic can be dealt with in

an expository manner or as a basis for creative diversion (create a new insect, plan a landing on Mars, write a poem from the perspective of a bird, etc.). Children's books are full of fact as well as fantasy. Listening skills are always focused on sounds in the physical world.

Social studies is such a natural for integration with science that it's hard to believe that integration doesn't always occur. Whether you are studying your students' families or neighborhood or more global studies, there are always elements of the studied topic which deal with science. These relationships can readily be seen when studying: technology; people; science related careers; industries; geography; or concerns, problems, and questions rooted in scientific understandings and applications.

The very production of musical sound is science. How sounds are produced; how varied instruments, bands, and orchestras create their ranges of sound; and why a given sound (or note) is the same yet different on different instruments, even the human voice, are all science related topics. Many colleges now have courses on the physics of sound. The technological applications which have brought about the fantastic music recording and reproduction industries are ripe areas for study. Listening skills and musical sounds are a natural match.

Literally any object a child chooses to draw, sculpt, or create in any other art dimension is an object which can be studied for its scientific value. The very act of reproducing an object in an art form requires detailed reproducing observation and examination of its various parts and their relationships. Close attention to colors and to one's own ability as an artist to create, combine, and reproduce those colors is science and can be extended to many understandings about light and color. Three dimensional art forms demand experimentation with gravity, balance, and sometimes motion.

Much of what happens in physical education which can motivate children to learn more about what they are experiencing in a particular activity. Students can begin with their own personal bodies and ask how they manage to move them around for the necessary range of motion for a particular physical activity. The various apparatus used in the many games that young people play lend themselves to learning more about force, motion, and gravity.

What's really happening when teachers start overlying curriculum areas as discussed above? They are putting the parts back into the whole. Teachers can become so

immersed in their teaching that they fail to notice the compartmentalized climate which may result. In the world outside the classroom, life does not split itself into separate curriculum areas. Yet what goes on in the classroom is primarily about the outside world. Educators sometimes forget what it's all about.

It is not only science that suffers from this myopic vision. Likewise, reading and mathematics need to be viewed as a means to an end. They represent skills which are meant to be applied to some exciting content. And science can be pretty exciting.

Teachers who integrate curriculum areas are building very important skills in young people which go far beyond content knowledge. Asking questions, seeking information and answers, critically evaluating, and making choices and decisions, are all skills for life!

GROUP INQUIRY

by Gerald Wm. Foster

"Hands-on, Minds-on" is often used to characterize a frame of reference for teaching science in the elementary classroom. The meaning refers to elementary students experiencing science through action on concrete objects for understanding basic scientific phenomena. But I would like to attach a slightly different meaning. Not only do children need the concrete *hands-on* experience, but they also need a *minds-on* experience through verbal interactions with other students. In other words, children also learn science by interacting with the ideas of others. Piaget (1966) states, *"As far as intelligence is concerned, cooperation is thus an objectively conducted discussion (out of which arises internalized discussion, i.e., deliberation or reflection), collaboration in work, exchange of ideas, mutual control (the origin of the need for verification and demonstration), etc. It is therefore clear that cooperation is the first of a series of forms of behavior which are important for the constitution and development of logic."*

What Piaget is saying is especially true for upper elementary grades and middle school students. Their maturity, experience, and logical development allow them to consider other possibilities and points of view that are different from their own internal sets of knowledge. This makes them capable of coordinating different viewpoints with their own viewpoints. In contrast, younger children

are usually only capable of relating to their own set of knowledge and not to that of others.

Before students can coordinate differing points of view of other students, they must have some understanding of the concepts under consideration. To gain this basic understanding, they need to process the concept through concrete experience prior to interacting with other students on the same concept. Otherwise, students may feel lost and incapable of participating in the group work. Possibly, this is the reason why many teachers observe some students in groups sitting back and letting other students do all of the work. For example, a student needs to have a personal cognitive structure for working with a group of students who are working with complex electrical circuits. If a student does not have a basic understanding of how to light a bulb, that he will not understand what the other students are doing or saying in relation to the circuits they are building. Activities on building electrical circuits appearing in this sourcebook are excellent examples of science activities that allow students the opportunity to develop and coordinate different points of view. There are enough materials and ways to devise circuits that each student can contribute to the development of circuits.

In most cases, a well functioning group will take on the characteristics of a unit or act as one individual. To achieve this, ground rules such as respecting the opinions of others and assigning each student a responsibility must be a priority in the formation of student groups. Thus, to some extent, individualized classroom teaching strategies can apply to individual groups. For example, groups work at different paces and extensions are needed for those who are getting bored or who have completed the initial stages of the activity before any of the other groups. Groups may have to be motivated in different ways to keep them on task. For example, one group may need clarification of the goals of the activity while another group needs to be reminded of the classroom rules for working in groups.

Another consideration in the formation of groups is their size and student mix. Groups of four to five students appear to be the optimum size. If the group consists of three people, often one feels left out of the group activities, or, if the group consists of two people, then the diversity of ideas is extremely limited. If the group is larger than five, it is possible that the group will break down into subgroups or that students can sit back and remain anonymous. Also, as the group gets larger, it becomes increasingly difficult to assign different responsibilities to each group member.

Groups should be heterogeneous rather than consisting of students of the same I.Q., sex, or socioeconomic background. In other words, certain student characteristics should not determine the makeup of the group. Group work ought to be fluid and dynamic, based upon cognitive needs of students rather than just an alternative to individualized work or whole group instruction. Working groups can be formed spontaneously as those needs arise. They can be readily dissolved when another form of instructional setting is appropriate. For example, students can develop classification schemes on their own. Those who finish early can share their schemes. They can discuss the differences and similarities of their schemes, modify their own, or work together to develop one main scheme from the individual work.

In summary, group inquiry in the science classroom can be very rewarding not only for the students but also for the teacher. It can be rewarding to the teacher in terms of seeing the diversity of opinions and creativity that can arise from a group. It can also be rewarding to see students who do not participate in large group activities share their ideas with others. In other words, a whole new viewpoint of individual students and their potential may emerge from observing student in group activities. For students, this may mean a stronger and more positive self-image than that they had before, because they can share their ideas and opinions to a small group of students and not feel intimidated by the whole class.

Thus, not only does group work help in the development of children both socially and intellectually, but it also puts them in situations similar to the everyday work of the scientist. Ideas in science are rarely shaped by one person's research but are shaped by the acceptance and rejection of other scientists. The more students understand how science works, the less alienation they will feel toward science.

Reference:

Piaget, Jean. (1966) *The Psychology of Intelligence*, Totowa, NJ: Littlefield, Adams, & Co.

CHAPTER - 2



Tuning-In to Sounds

by Gwyneth E. Loud

Focus:

Most of the time we live in a noise filled world. We get so used to the sounds and noises around us that we do not even notice most of them and they blur into general background noise. This is a sensory activity which heightens awareness of the sounds around us.

Challenge:

When we close our eyes and focus attention on the sounds around us, what do we hear?

Materials and Equipment:

Pencil

Paper

Procedure:

This activity can be done with any size group, indoors or outdoors. (If the group is outdoors and lying on grass, leaves, pine needles, etc., this is a sensory experience in itself and usually requires several minutes for the group to feel comfortable, settle down, and stop talking.) Sit or lie quietly with eyes closed for a given length of time (3-10 minutes, depending on the age and interests of the children). Older children make their own lists of all the sounds they hear, manmade as well as sounds of nature. After the time is up, gather together and share lists or make a large group list of all the sounds heard.

Further Challenges:

- ☐ Think of ways to classify the sounds heard, e.g., high/low pitch, duration, made by living or non-living objects, natural or manmade, etc.
- ☐ Discuss or do research about how well animals other than humans hear. Dogs, bats, and insects, for example, can hear pitches out of the human range. Some children will know about echolocation used by such animals as dolphins and bats.
- ☐ Discuss health and social effects of noise pollution and high decibels.

☐ Have students use tape recorders to record sounds in the environment.

☐ Play identifying "mystery sounds" games. Most libraries have records of various animal and environmental sounds which can be used for these games. Common household and school sounds could also be tape recorded if commercially produced materials are not available.

References:

Allison, Linda. (1976) *Blood and Guts*. Boston: Little, Brown and Co.

Russell, Helen Ross. (1973) *Ten-Minute Field Trips* Chicago: J. G. Ferguson,



The Paper Whistle

by Linda Froschauer

Focus:

This and related lessons teach children that sound is caused by vibrations. Energy is necessary for sound to occur. The source of energy varies. In the case of the activities that follow, the energy source is the person conducting the activity. (If an object vibrates 16 times per second or faster, the sound can be heard by humans. If the object vibrates faster than approximately 20,000 times per second, humans cannot hear the sound.) Sound must have a conductor. That conductor may be air, a solid, or a liquid. There is no sound in space because there is no atmosphere to serve as a conductor.

Challenge:

After constructing this instrument, students will look for evidence of what causes sound.

Materials and Equipment:

Paper template
Scissors

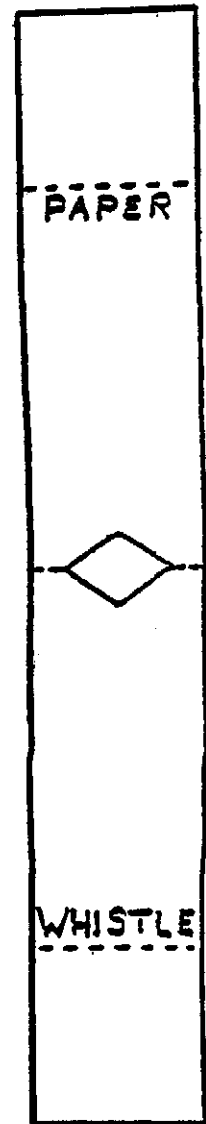
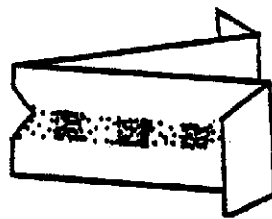
Procedure:

Have students cut out the paper whistle found on this page. The solid lines should be cut out, making sure to cut out the diamond shape in the center. Next they should fold along the dotted lines.

They should hold the whistle to their lips, separate the pieces of paper slightly, and blow sharply. Ask them to try to explain how the sound is formed, based on their observations. It may be helpful for them to place their thumb and index fingers around a partner's whistle as it is being blown.

Further Challenges:

- ☐ What can you do to change your whistle so that it makes a different sound?
- ☐ What is the smallest or largest whistle you can make that will still create sound? How does the sound of a larger or smaller whistle differ from the sound of the original one you made?



The Soda Straw Whistle

by Linda Froschauer

Focus:

Reinforce concepts introduced in "The Paper Whistle."

Challenge:

With this new instrument it is not possible to see evidence of what makes the sound. But, is it possible to feel evidence of what makes sound?

Materials and Equipment:

2 soda straws
Scissors

Procedure:

Flatten about 2 cm ($\frac{3}{4}$ in) of one end of a soda straw. Placing the straw between your teeth and biting down hard while pulling it out of your mouth works quite well. Cut away a small triangle on each side of the flattened end of the straw to form a point as shown on this page.

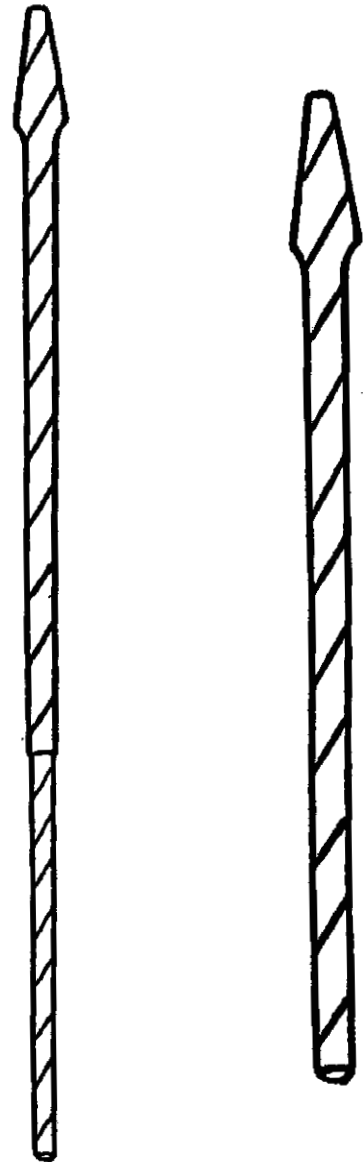
Put the flattened end in your mouth and blow hard. It is necessary to put the straw deep enough into your mouth so that the tip is not touching the lips or tongue. The teeth should be held slightly apart so they do not interfere with the straw's vibration or air flow. If you do not hear a sound, you may need to flatten the end of the straw a bit more.

Ask students to describe what they feel when they blow into the straw.

Further Challenges:

- ☐ Try to make a soda straw whistle that is shorter than the one just made. Compare the sounds it makes with the other one.
- ☐ Make a whistle that is higher in pitch than either of the straw whistles you have made thus far.
- ☐ Get a group of friends together and create a band. Each player should have a whistle with a different pitch. Can you play a simple song?

- ☐ Make a straw whistle that is narrower than the one first made. How is the sound different?
- ☐ Place a straw that is narrower into the bottom of the first straw whistle. Slide it up and down as you are blowing. What musical instrument works on a similar principle?
- ☐ Join several straws together to make a very long whistle. Try blowing into it. What did you find out? Why does this happen?



The Cardboard Tube Kazoo

by Linda Froschauer

Focus:

Reinforce concepts introduced in "The Paper Whistle".

Challenge:

Don't be fooled. There are several things that vibrate when using this instrument. Think about all of them as you work on this project.

Materials and Equipment:

Toilet paper roll
Wax paper
Rubber band
Sharp pencil

Procedure:

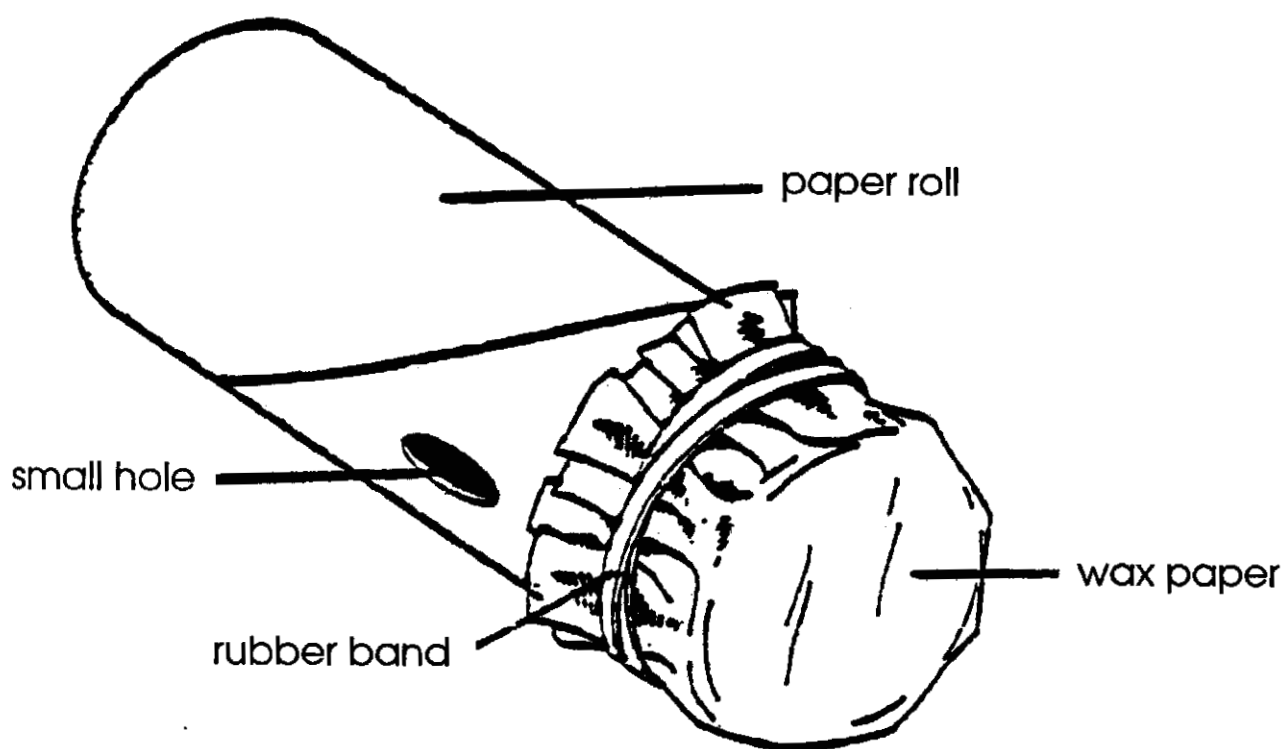
Wrap a 10 cm by 10 cm square of wax paper around the end of a cardboard tube. (Empty toilet paper roll tubes are a particularly good size.) Secure the wax paper in place (as

shown) with a rubber band. About 2 cm from the covered end, make a small hole with a sharp pencil.

Instruct students to hold the open end of the instrument to their mouths. They should open their mouths slightly and hum a tune. Ask them to identify everything that vibrates to make sound.

Further Challenges:

- ☐ What causes the sound?
- ☐ What changes the pitch?
- ☐ What changes the sound?
- ☐ Would a longer tube sound different? Try using a tube from a paper towel or gift wrapping.
- ☐ How would the sound be affected if something other than wax paper were used to cover the end? They might wish to try newspaper, aluminum foil, tissue paper, etc.



The Paper Cup Noise Maker

by Linda Froschauer

Focus:

Reinforce concepts introduced in "The Paper Whistle."

☐ What is the source of the energy for sound in this activity?

Challenge:

☐ What is the sound conductor? amplifier? receiver?

Vibrations in this instrument are not as obvious as with previous instruments. Students should be instructed to think about what must be vibrating (even though no vibrations can be seen) as they are constructing this device.

Materials and Equipment:

Paper cup	Fabric
String	Paper towel
Toothpick	Water

Procedure:

Use a toothpick to punch a hole in the center of the bottom of a paper cup. See the diagram on this page. Thread a piece of string approximately 60 cm (24 in) long through the hole. Tie the toothpick to the string so that the toothpick will be on the inside of the cup. Pull on the string so that the toothpick lies flat on the bottom of the cup. It may be necessary to break off one end of the toothpick if it is too long.

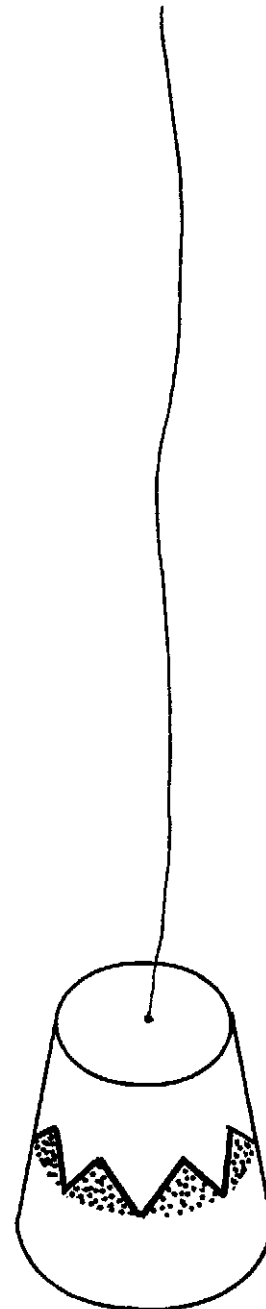
Hold the cup in one hand and the end of the string in the other. Have a partner hold a piece of fabric between their thumb and index finger and rub it along the string. Have them try to explain what produces the sound.

Further Challenges:

☐ Try several different materials on the string. Does the sound change with different materials?

☐ Dampen the piece of fabric. Rub it along the string. What is the type of sound made when the wet fabric is rubbed along the string?

☐ Substitute a rubber band for the string. Pluck the rubber band with your finger. Note the sound produced. How does the sound change as the rubber band is stretched more tightly?



Visible Vibrations

by Gwen E. Loud

Focus:

The concept of sound waves, or vibrating air molecules, is hard for some children to grasp because it is so abstract and invisible. If "seeing is believing" these activities should help children realize that when a sound is made, vibrations are created.

Challenge:

What happens when a tuning fork is struck and then touched to a movable object such as a ping pong ball or water?

Materials and Equipment:

Ping-pong ball
Thread
Tape
Tuning fork
Shallow pan of water
Overhead projector
Shallow clear plastic container of water

Procedure:

The first two activities are best done in groups of eight to ten to avoid a lot of waiting for each child to take a turn.

1. **Ping-pong ball vibrations:** Hang a ping-pong ball with tape and thread from the edge of a desk or table. Make sure the ball is hanging still. Strike the tuning fork and quickly touch a tine lightly to the ping-pong ball. The ball should start "dancing" back and forth, showing that the tines of the tuning fork are vibrating as it is creating sounds.

2. **Vibrations in water:** Set a pan of water on the floor or table where a group can gather around it. Strike the tuning fork and quickly touch the tines to the *surface* of the water. The vibrations should create little splashes, and delight the children.

3. **Vibrations in water using the overhead projector:** This activity can be used with larger groups because it is a demonstration by the teacher, visible on a screen. Set a shallow clear plastic container of water on the overhead

projector. Strike a tuning fork and quickly touch the tines lightly to the water surface. The vibrations should be clearly projected on the screen.

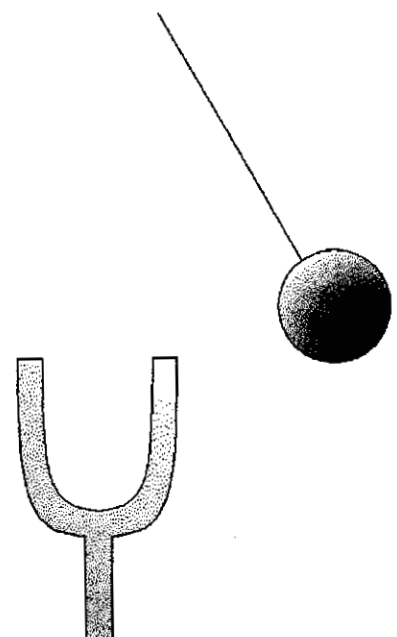
Further Challenges:

- ☐ Do these experiments mean that every time a tuning fork is struck vibrations are caused? If so, why don't we see the table or floor vibrating?
- ☐ Think of other ways to show that sound creates vibrations (including the classic twanging of a rubber band).
- ☐ Every time we see something vibrating, does that mean there is sound also? If so, why is no sound heard when a hand is waved back and forth? This leads to another subject: the ability of the human ear to hear sounds only within certain frequencies.

References:

Schmidt, Victor E. and Verne N. Rockcastle. (1968). *Teaching Science with Everyday Things*. New York: McGrawHill.

Stein, Sara. (1979) *The Science Book*. New York: Workman Publishing.



The Pitch and the Pendulum

by Marilyn Donalson

Focus:

After completing other activities in this sound chapter, the children will come to understand that pitch is determined by how fast or slow an object vibrates. This pendulum activity graphically demonstrates that long things usually vibrate slower than do short things and thus have a lower pitch.

Materials and Equipment:

String (varying lengths from 10 cm to a meter)
Masking tape
Timer or clock with second hand
Washer

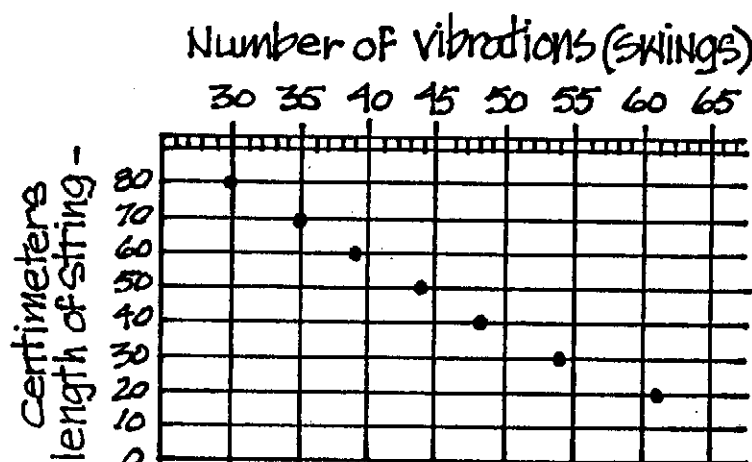
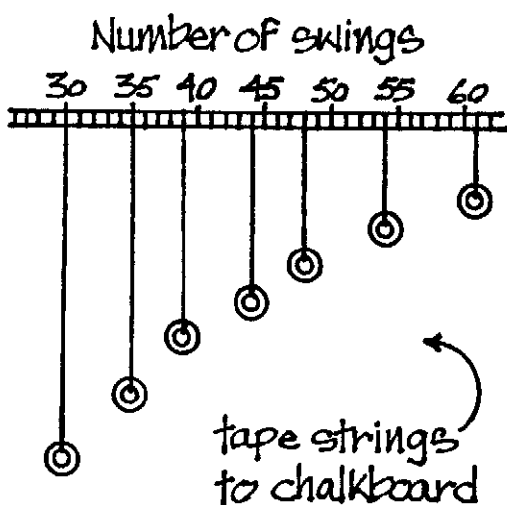
Procedure:

Refer to the drawings below. Give each child a piece of string, varying in length from 10 cm to a meter. Have them tie their washer to one end of the string. Be sure that everyone is spaced far enough apart to keep their strings from getting tangled. Have them practice swinging the pendulum while holding their arm still. Then have them

take the end of the string in one hand (the arm should be extended slightly), and hold the washer out level with the other hand. When the teacher says "Go", they let the washer go, and count one number for every forward and backward motion. *They must count silently* as they will not all be counting at the same speed. Practice doing this a few times, and then time them for one minute. On the blackboard, record (in ascending order by 5's) the number of swings for each pendulum. Give each child a piece of tape and have them place their pendulum below the correct number. They should notice that the shorter pendulums have a higher number of swings, and vice versa. You might also have them make a graph by measuring the length of the string plotted against the number of vibrations. It won't be a perfect ascension, but it should show a basic pattern. This would be a good time to talk about variables, and why everything didn't come out perfectly.

Further Challenges:

- ☐ From the data table compiled in class, can students predict the number of swings per minute of a longer pendulum? A shorter pendulum? The swing in the school yard?



Pitch Paradox

by Donna Gail Shaw

Focus:

The more there is of something vibrating, the lower the sound. The less there is of something vibrating, the higher the sound. The following activity presents an event that appears to be discrepant until you think about what is doing the vibrating to make the sound. When blowing, the air is vibrating; a larger column of air (empty bottle) produces a lower sound. When tapping the bottle, the bottle and its contents are vibrating; a full bottle produces the lower sound. In each case the larger mass produces the lowest sound.

Challenge:

Observe what happens when you blow across the tops of several soda bottles with varying water levels. Next, observe what happens when you tap these same bottles with a pencil. Make inferences about the differences in pitch.

Materials and Equipment:

8 or more soda bottles
Water
Pencil

Procedure:

1. Many students have blown across the tops of soda bottles and noticed the sound they make with varying levels of liquid. Many have even tapped bottles to make musical sounding tones. However, few have compared the sound made when blowing and the sound made when tapping.

2. Fill eight soda bottles with varying levels of water so that a "musical" scale may be played when tapped. (See the diagram below for a suggestion of how to arrange the soda bottles.)

3. Have a student come to the front of the class and tap the bottles using a pencil. You might even want to have the student play a very simple song on the bottles.

4. Next, have another student come to the front of the room to play the same scale or song. However, this time have the student blow on the bottles.

5. The class will soon notice that the scales or song don't sound the same. The tones are reversed!

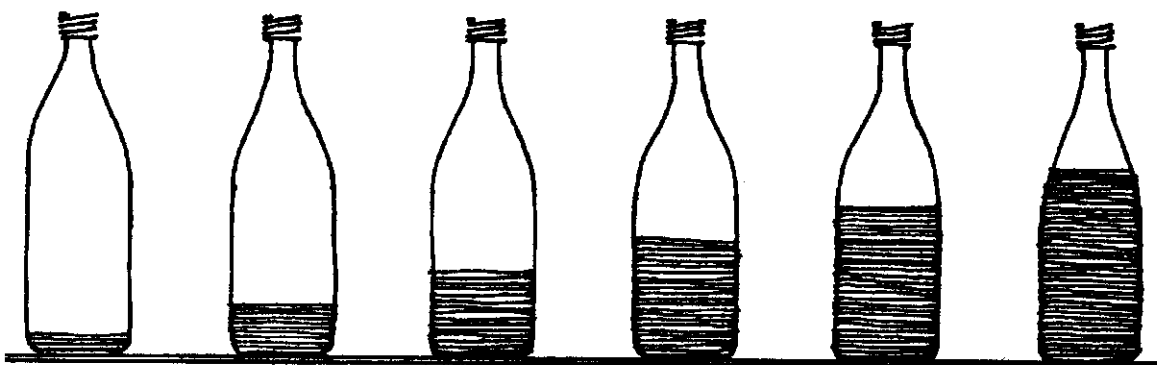
6. Lead the class in a discussion about how this might be explained. What causes sound? Have the students use their observing skills to notice the relationship between the amount of water and the sound. Have them use their inferring skills to determine why the sounds reverse when you tap or blow.

Further Challenge:

☐ Blow over a straw and notice the sound. Place one end of the straw in a glass of water and blow. Raise and lower the straw in the water and blow. You will notice as you lower the straw into the water, the air column becomes shorter and the pitch becomes higher.

Reference:

Friedl, Alfred E. (1986). *Teaching Science to Children*. New York: Random House, Inc.



Sound With A Pipe Xylophone

by Rose West

Focus:

Children of all ages enjoy making sound. This activity will focus on producing a pipe xylophone. The student will develop an understanding that different length pipes create different tones. The shorter pipe compresses the sound waves closer together thus producing a high pitch. The longer pipe allows the sound waves to spread apart, thus producing a lower pitch.

Challenge:

What can you discover about sound from a pipe xylophone?

Materials and Equipment:

13 mm (1/2 inch) electrical metallic tubing (conduit),
approximately 3 meters (10 feet) long
Foam padding (approximately 2 cm thick)
One board (approx. 30 x 60 x 2 cm thick)
Two dowel rods
Two wooden drawer knobs or tinker toy wheels
Hack saw or pipe cutter

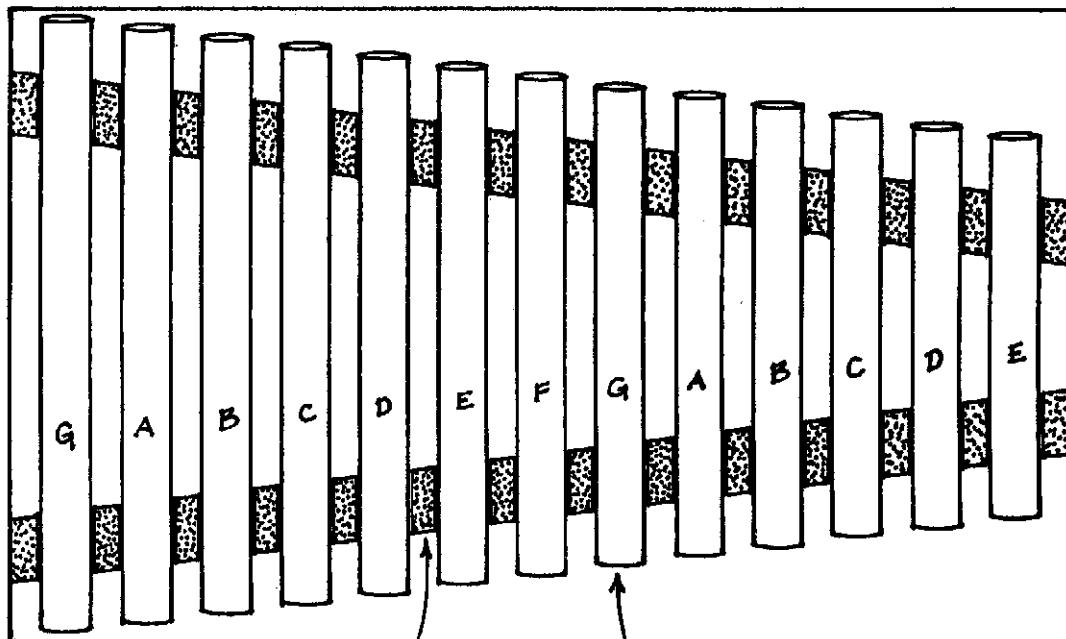
Scissors
Glue

Ruler
File

Procedure:

Refer to the diagram at the end of this activity. Cut the conduit with a hack saw or pipe cutter into the following lengths:

29.9 cm (11 3/4 inches)	sol - G
27.7 cm (11 3/32 inches)	la - A
26.0 cm (10 7/16 inches)	ti - B
23.3 cm (10 1/8 inches)	do - C
23.9 cm (9 9/16 inches)	re - D
22.6 cm (9 1/16 inches)	mi - E
21.8 cm (8 3/4 inches)	fa - F
20.5 cm (8 7/32 inches)	sol - G
19.5 cm (7 13/16 inches)	la - A
18.1 cm (7 1/4 inches)	ti - B
17.6 cm (7 1/16 inches)	do - C
16.5 cm (6 5/8 inches)	re - D
15.5 cm (6 7/32 inches)	mi - E



foam spacers
- glue to foam strip

conduit-
metal pipes

Smooth the edges with a file. It is better to cut the pipe too long and sand off the extra length rather than cut the pipe too short!!

Cut the foam to make two long strips about 4 cm wide and 60 cm long. You will also need 28 small foam pieces for spacing between the pipes. These should be cut approximately 1.5 x 3 cm long. These can be cut in a parallelogram shape so they will align with the slanted supports.

Lay the strips of long foam on the board to form a V shape. The wide point should be about 20 cm apart and the small end about 1 cm apart. The pipes will then be supported at the points that create the least interference with the music.

Attach the pieces of foam to the wood with plenty of white glue. The spongy material tends to absorb the adhesive quickly. *Self sticking foam (weather stripping) is also available. It may be somewhat easier to work with this material. It is considerably quicker as no time is required for glue to dry.*

Glue the first pair of small foam strips flush with the ends of the strips just to the left of the point where the longest pipe will be located. Lay the longest pipe in place barely touching the spacers. Glue on the next pair of small foam strips and continue until all pipes and foam strip spacers are in place. The pipes can then be removed while the glue dries.

On the board below each pipe, label the note value. The longest pipe is G and the notes continue as listed above.

Mallets can be made from a dowel rod and wood drawer knob or tinker toy wheel. Place the drawer knob or tinker toy wheel on the end of the dowel rod. *As an alternative you may wish to purchase mallets.*

Your pipe xylophone is now complete and ready to use.

Discussion Questions:

What causes sound? Vibrations produce sound waves. These waves are series of compressions and refractions. A compression squeezes air together. Refractions spread the waves of air apart.

How does sound travel? Sound goes through air in all directions. Sound must have matter to conduct it.

What is pitch? Pitch is the range a note can produce high or low. The pitch is controlled by how slowly or rapidly the sounds or sound waves vibrate. In high pitch the sound waves are compressed closer together. In low pitch the sound waves are further apart.

What happens to sound as it travels? Some objects absorb sound, i.e., furniture, carpets, curtains. Some objects reflect sound, i.e., bare floors, empty rooms.

Further Challenges:

- ☐ Can you produce a different sound by changing the mallets?
- ☐ Try to make a stringed instrument by using various types of strings cut to different lengths.
- ☐ Try to produce a wind instrument.
- ☐ Try to produce some percussion instruments.
- ☐ Do research on early instruments.

References:

Mother Earth News (1984). *Simple Instruments to Make and Play*. Box 70, Hendersonville, NC, 28719.

A Race Between Sound and Light

by Gweneth E. Loud

Focus:

This activity is designed to show that there is a difference between the speeds at which sound and light travel. *Sound travels at 1/5 mile per second and light travels at 186,000 miles per second.*

Challenge:

Find out which travels faster: sound or light?

Materials and Equipment:

Flag (or easily visible piece of cloth or paper)

A loud noisemaker (such as a drum, horn, cymbals, or pot lids)

Procedure:

This activity can be done with a group of any size. It must be done in a large flat open area such as a playing field or park. There must be good visibility from one end of the space to the other.

Two students go to one end of the field with the instrument and the flag. The rest of the class lines up at the other end of the field, watching the first two, in silence.

At exactly the same moment, one student makes a loud noise with the instrument and the other raises the flag overhead.

The rest of the class should see the flag go up before the sound arrives, illustrating that light travels faster than sound.

Further Challenges:

- ☐ Do the same activity several times, but move the two students closer to the group each time to discover at what distance the group sees the flag and hears the sound at the same time.
- ☐ Using the instrument and the same open space, experiment to see at what volume the noise must be made for the group to hear it at various distances. These

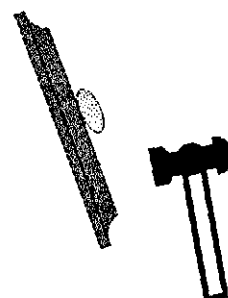
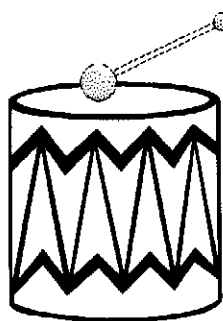
activities provide opportunities for students to practice measuring distances and making charts and graphs.

- ☐ Observe and listen to jet planes as an example of the differing travel speeds of sound and light. The sound always seems to travel behind the plane.

References:

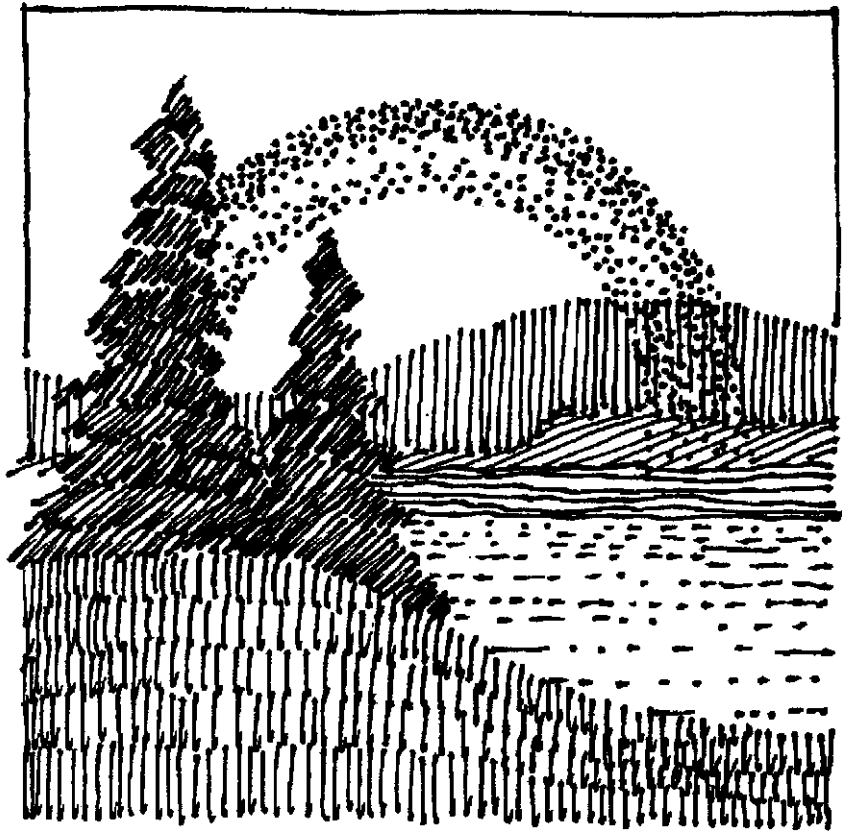
Schmidt, V.E. and V.N. Rockcastle (1968). *Teaching Science with Everyday Things*, New York: McGraw-Hill.

Stein, S. (1979). *The Science Book*. New York: Workman Publishing.



CHAPTER 3

LIGHT AND COLOR



a rainbow as seen from Earth...
appears half-hidden

Retinal Fatigue and Color

by Michael J. Demchick

Focus:

The retina of the eye becomes tired of continuously attending to one specific color. As a result, the eye sees the complement of that color. This condition is called retinal fatigue.

Challenge:

What is the complement of each primary color? How does the eye perceive a color after attending to it continuously for several minutes?

Materials and Equipment:

American flag
Several white poster boards
Colored construction paper
Magic marker

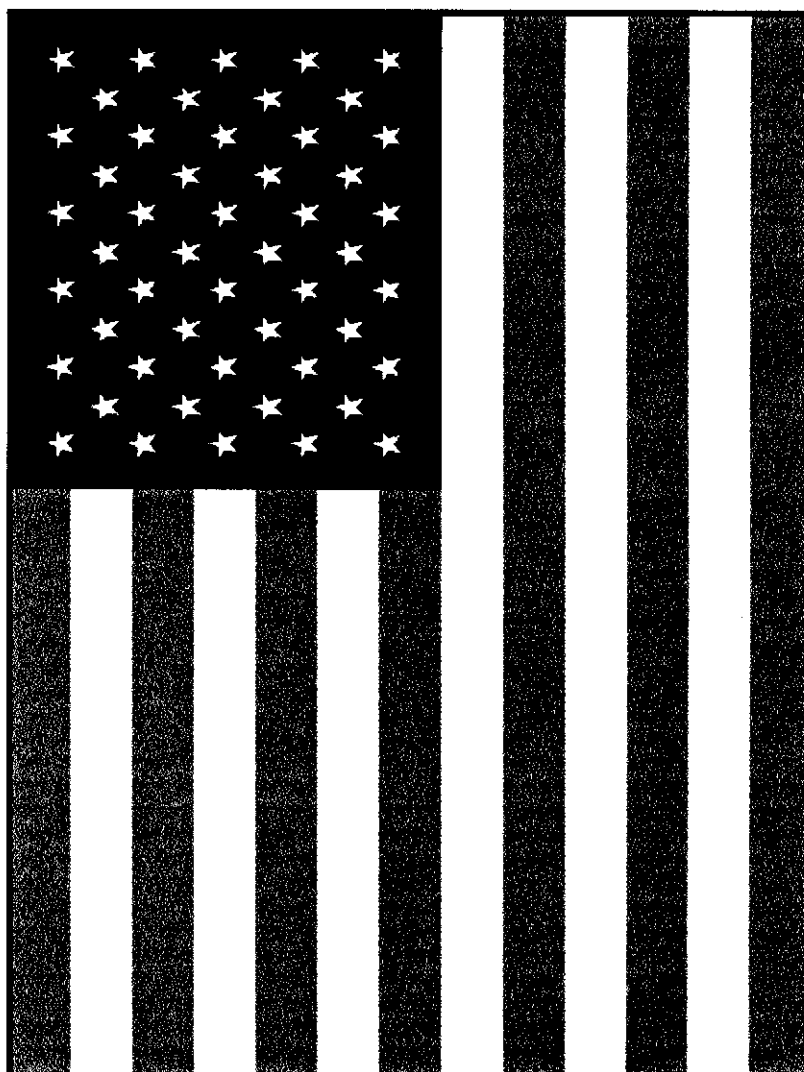
Procedure:

Outline several pieces of colored construction paper with a black magic marker. Use yellow, cyan (blue-green), and white construction paper. Attach each to separate pieces of white poster board. Ask the students to stare at one of these colors for about one minute without blinking. Then have them move their eyes slightly to focus on the white poster area and observe the results. The result is the complement of the observed color.

Place an American flag across the front of the blackboard and a piece of white poster board next to it. Stare at the star in the inside corner of the flag for about one minute. Shift the eyes slightly to the white poster board. Results? How do you account for what you see?

Further Challenge:

☐ Use a different color poster board with the same colors as used with the white poster board. See if you can account for the results.



☐ Create pictures that are the opposite of their actual color with construction paper. For example, create a black snowman with white eyes, nose, mouth and buttons. Place the snowman in front of a red pine tree with a orange sky and purple sun in the background. Stare and look away to a white sheet of posterboard as you did with the flag before. You will see a white snowman in front of a green tree and a yellow sun. Let students get creative in making positive pictures from negative images.

The Thaumatrope

by Linda Froschauer

Focus:

Persistence of vision is the ability of the eye to retain an image for at least 1/15 of a second. Therefore, if we see more than 15 images in a second, our brains perceive motion or a blend of images and color. This phenomenon is the basis for the production of movies, television, and cartoon animation. Motion pictures at your hometown theater project 16 frames per second. Your television set flashes approximately 60 images per second on its screen. Without the "persistence of vision" these flashes would be just a series of pictures and would not be perceived as movement.

Challenge:

After trying your thaumatrope several times, explain what you think "Persistence of vision" means.

Materials and Equipment:

White oak tag
String
Marking pens
Scissors

Procedure:

Cut out a 75 mm (3 inch) circle of oak tag. Create a design on each side of the oak tag circle. A different color should

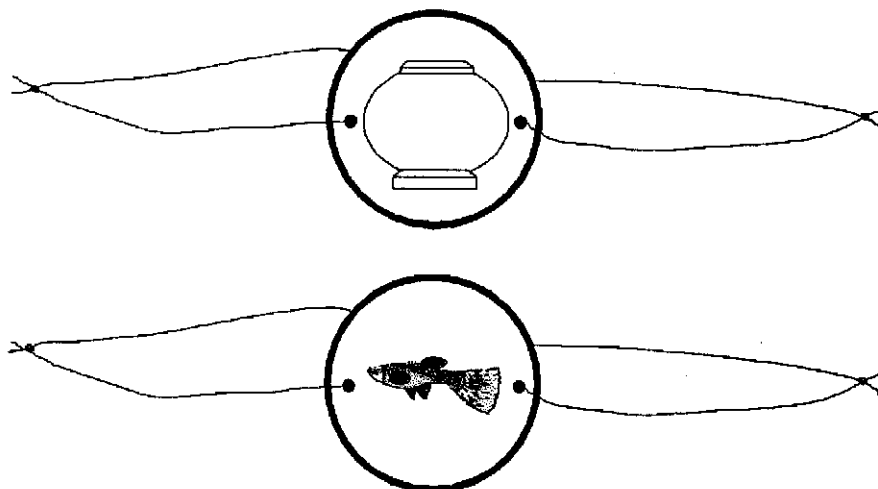
be used for each side. Each side should be part of a total drawing. For example a large fish bowl could be drawn on one side of the circle and a small fish drawn on the other. When the drawing is spun as explained below, the fish will appear to be inside the fish bowl. Other possibilities include: a cat and a basket, a spider and a web, a frog and a lilly pad, flowers and a vase.

Use a sharp pencil to make two holes on opposite sides near the edge of the disk. Thread a string (approx. 24 cm or 8 inches in length) through the two holes. A knot should be tied at each end. (See the drawing on this page.)

Hold the end of each string loop and wind it up by swinging it over. It should be consistently wound in one direction. When it is wound tightly the ends of the string should be pulled gently. This should cause the disk to rotate. Students should observe carefully and describe their findings.

Further Challenges:

- ☐ Can this be done using oak tag cut into shapes other than a circle?
- ☐ Can this be done using a larger or smaller disk? Try making a large thaumatrope. What is the biggest problem with getting a very large thaumatrope to work?



The Chromotrope

By Linda Froschauer

Focus:

This activity reinforces the concept of *persistence of vision*. It also demonstrates the additive effect of mixing colors of reflected light. As two or more colors are spun on the chromotrope at the same time, reflected light from the multiple colors reaches the eye at nearly the same instant. This has the effect of mixing the colors of light.

Challenge:

What effects do different color combinations have on what you see? Can you determine which colors combine to produce new apparent colors on a chromotrope?

Materials and Equipment:

White oak tag
String

Marking pens
Scissors

Procedure:

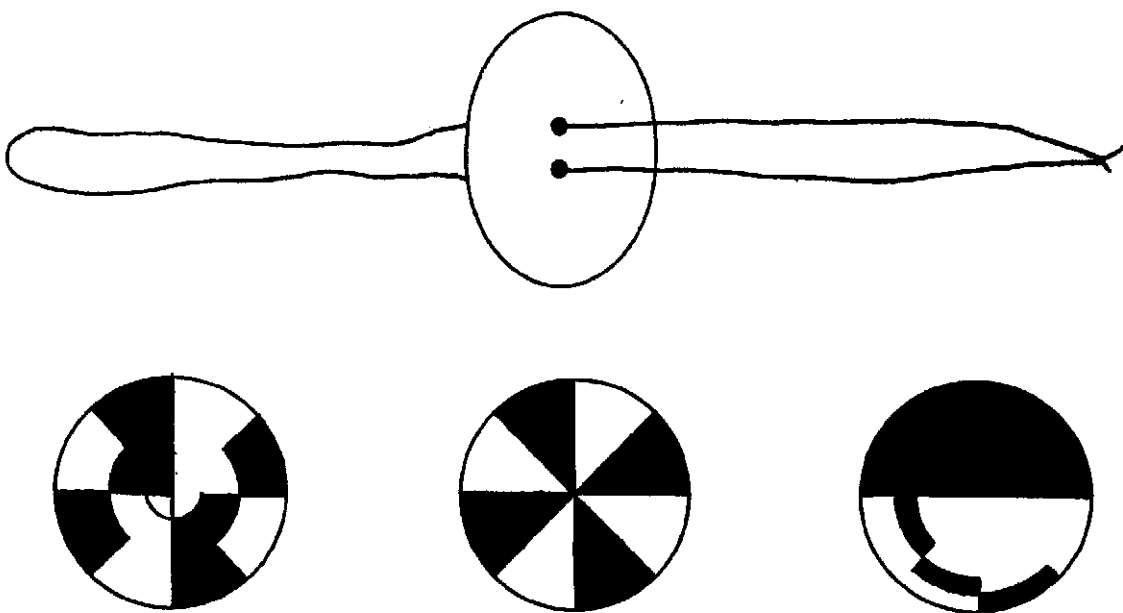
Make a 75 mm (3 inch) circle of oak tag, create a colorful geometric design on each side. (See examples at the bottom of this page.) Use at least two different colors. Make the design on each side different from the other by using different color combinations.

Use a sharp pencil to make holes 20 mm (3/4 inch) apart near the center of the disk. Thread a 100 cm (40 inches) piece of string through the two holes as shown. Tie the ends of the string in a knot.

Hold each end of the string loop and wind it up by swinging it over in a consistent direction. When it is wound tight, gently pull the ends of the string apart with your hands and then relax your grip. With a little practice of repeatedly pulling and relaxing your grip, the disk can be kept spinning indefinitely.

Further Challenges:

- ☐ Try new color combinations and patterns to create new effects.
- ☐ What is the longest period of time you can keep your chromotrope spinning? What variables effect how long it will spin?
- ☐ Stare at something really hard for several seconds. Close your eyes and describe what you see. How is this an example of "persistence of vision."
- ☐ Make black and white patterns as shown below. How many colors can you create from spinning black and white patterns?



The Pinwheel

by Linda Froschauer

Focus:

This is a toy most children have played with at one time. This activity will take a closer look at it to reinforce the concept of *persistence of vision*. It also demonstrates the additive effect of mixing colors of reflected light. As two or more colors are spun on the pinwheel at the same time, reflected light from the multiple colors reaches the eye at nearly the same instant. This has the effect of mixing the colors of light.

Challenge:

Place two primary colors on your pinwheel (such as yellow and blue). What happens to the colors when you get the pinwheel spinning very fast?

Materials and Equipment:

White paper
Pencil
Thumbtack

Marking pens
Scissors

Procedure:

See the drawings on this page. Cut out a 25 by 25 cm (10 x 10 inch) square of white paper. Using a ruler, draw two diagonal lines connecting opposite corners of the square. The two lines should cross at the exact center of the paper. Make patterns on each section drawn and color them. Use at least two colors.

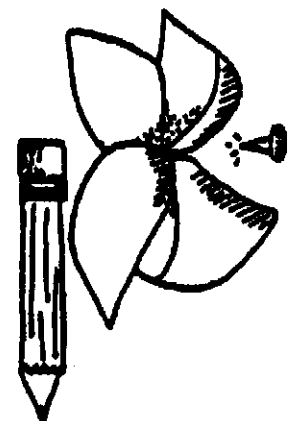
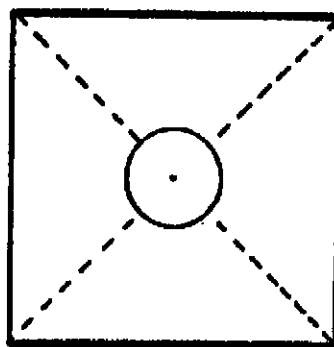
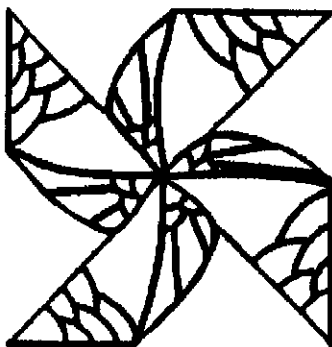
Draw a circle of about 35 cm (1/2 inch) diameter in the exact center of the paper. Cut along the lines drawn from the corners up to the circle. Do not cut all the way to the center!

Bend one corner of each of the triangular areas toward the center of the paper and secure them by pushing a thumbtack through each corner and the center of the paper. Push the thumbtacks into the eraser of the pencil.

If there is sufficient breeze, the pinwheel should spin freely on its own. If there is no breeze, it will be necessary to blow on it. Students should observe colors and patterns created as the pinwheel spins.

Further Challenges:

- ☐ Make a variety of pinwheels using colors or different patterns in the designs. Which ones do your eyes tend to blend together? Which designs can be clearly seen no matter how fast the pinwheel spins?
- ☐ Which way does the pinwheel spin? How could it be made to spin in the opposite direction?
- ☐ Can a pinwheel be made in shapes other than a square? What about a triangle? A circle? A hexagon?
- ☐ Experiment with other materials to try and make the pinwheel spin faster. (*Hint: Cut down on the friction created by the paper touching the eraser.*)



The Phantascope

by Linda Froschauer

Focus:

This activity explores a device once known as the "magic disk" or *Phantascope*. This was a childrens' toy capable of showing moving pictures created before the invention of the motion picture projector.

Challenge:

Make a series of drawings on a phantascope that depict some type of motion.

Materials and Equipment:

Marking pens	Thumbtack
Pencil	Phantascope template
Scissors	

Procedure:

Copy the phantascope template on the following page. Cut out the phantascope disk and the viewing slits. Draw an action picture on each line above the viewing slits. These eight pictures will need to be drawn in sequence. Students may wish to make practice drawings on scrap paper before beginning. The drawings may be colored if desired.

Push a thumbtack or straight pin in through the center of the disk and into the eraser of a pencil. The pencil should be on the blank side of the disk.

Stand in front of a mirror and hold the phantascope at eye level such that you can see through the viewing slits. Spin the disk and watch through the slits. Students should describe what they see occurring.

Further Challenges:

☐ Try making another phantascope showing a series of pictures that are continuous and nonstop motion.

The pattern of motion should repeat over and over again. Some possible topics include: a person peeking out of a doorway, pulling back, and peeking again; someone in a rocking chair moving back and forth; a worm moving into and out of an apple.

☐ Instead of drawing a series of pictures on the phantascope, try making designs using different colors.

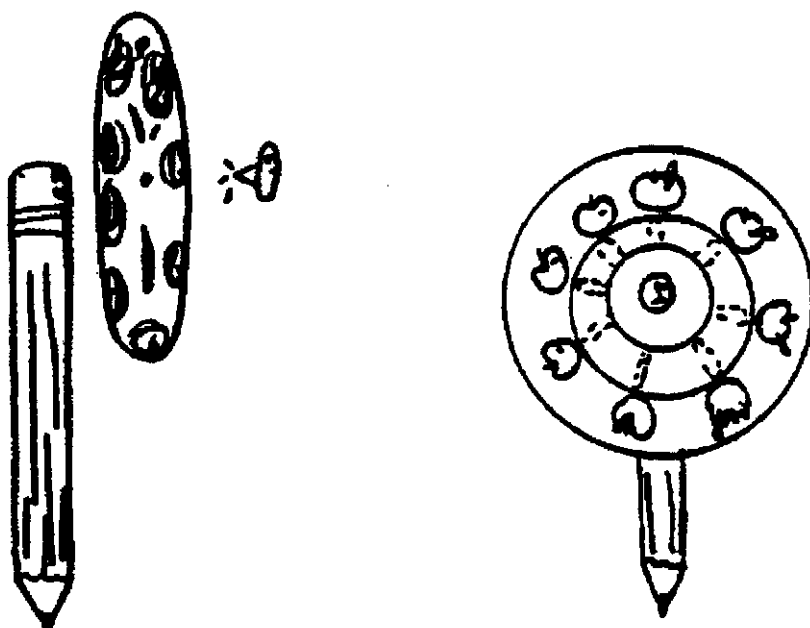
☐ Make a flip book. Staple together several small pieces of paper or index cards. Draw a figure on each piece of paper. Each drawing should represent one phase of the moving figure. Flip the pages with your thumb and watch the figure move.

☐ The phantascope works on the principle of optical illusion. Find other examples of optical illusions and share them with the class.

☐ Design a much larger phantascope with more viewing slits and a longer action sequence. How large a phantascope can you make?

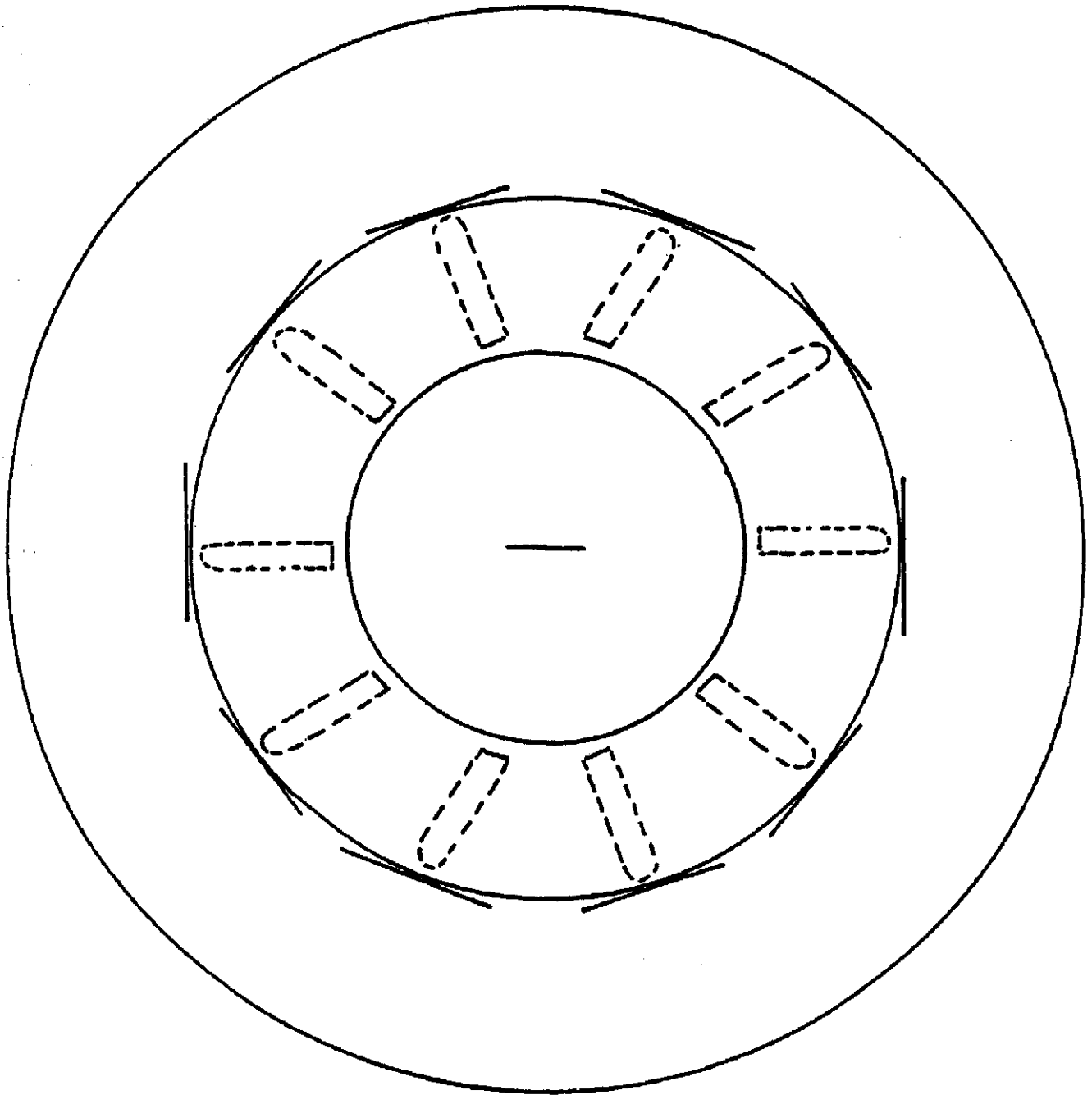
Reference:

Caney, Steve (1972). *Toy Book*. New York: Workman Publishing.



Phantascope Template

Reproduce copies for each group.



The Taleidoscope

by Linda Froschauer

Focus:

This instrument is actually more familiar to children when its mechanism is covered. It is the inside workings of a better known instrument called the kaleidoscope. Students are able to use this device to explore the effects of multiple reflections in plane mirrors.

Challenge:

Describe in your own words how a taleidoscope works.

Materials and Equipment:

Black tape
Microscope slides

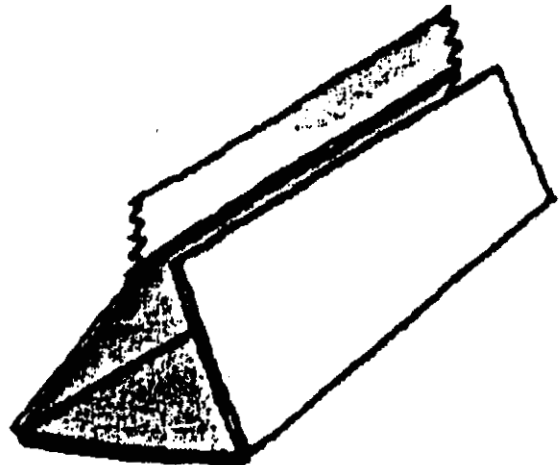
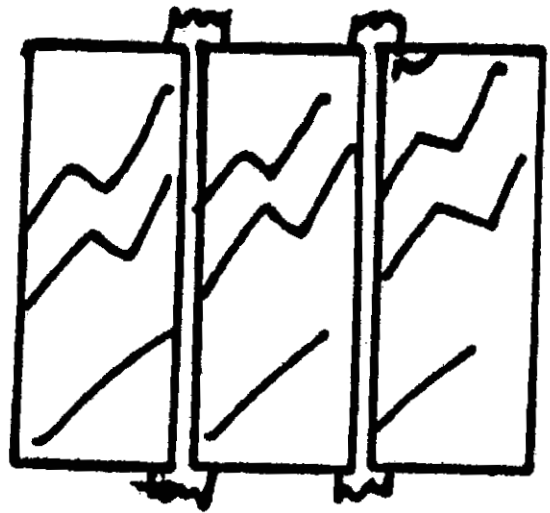
Procedure:

Place three microscope slides next to one another on a flat surface with their long edges almost touching. (*See the top figure on this page.*) Connect the slides to one another using black tape. Turn the slides over so that the taped side is touching the table. Fold two of the slides up so that they touch one another. You should have formed a triangle. (*See the bottom figure on this page.*) Connect these two slides to one another. Take a look at the triangle formed. If any of the glass is still bare (*not covered with black tape*) cover it with small strips. Look at any objects around you through the taleidoscope. It works best when there is a lot of light on the object. Investigate various objects and patterns with the device.

Further Challenges:

- ☐ Try making a four sided taleidoscope. How is the view different from the three sided version?
- ☐ Make a large taleidoscope. Use acetate sheets such as overhead projector sheets or report covers instead of the slides. Strips approximately 5 x 20 cm work quite well. The acetate strip may be painted or covered with black tape on one side. They should be connected like the taleidoscope above.

- ☐ Hold a magnifying glass in front of the opening of the taleidoscope. Have students describe the results of this variation.
- ☐ Try writing your name while looking through the taleidoscope.



The Kaleidoscope

by Linda Froschauer

Focus:

Exploration of multiple reflections in a plane mirror.

Challenge:

Describe in your own words how a kaleidoscope works.

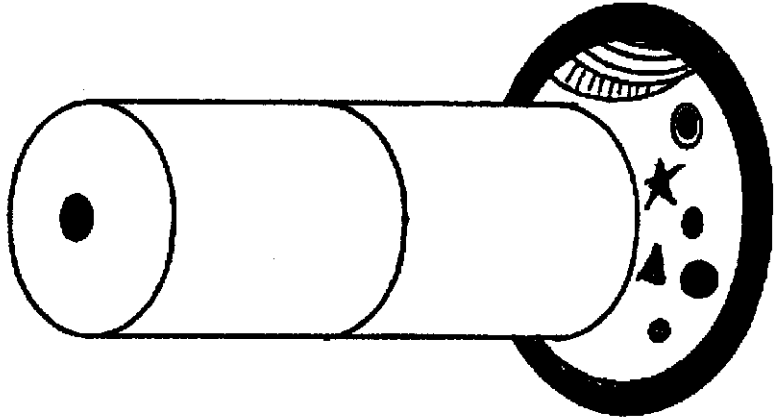
Materials and Equipment:

Black tape	Scissors
Microscope slides	Glue
Clear acetate sheet	Beads
Straight pin	Ribbon
Marking pens	Colored cellophane
Film canisters	Tape

Procedure:

Construct the kaleidoscope from the previous activity. Cut the end off of one plastic film canister. Put a hole approximately 1 cm in diameter in the end of another film canister. Attach the two canisters with tape. The open ends should be touching. Insert the kaleidoscope into the tube you have made.

Cut an 8 cm disk out of the acetate sheet. Glue beads, scraps of paper, ribbon, cellophane, etcetera onto the disk.



Push a pin through the center of the disk and the lip of the canister. *Be cautious with the pin when piercing the canister.*

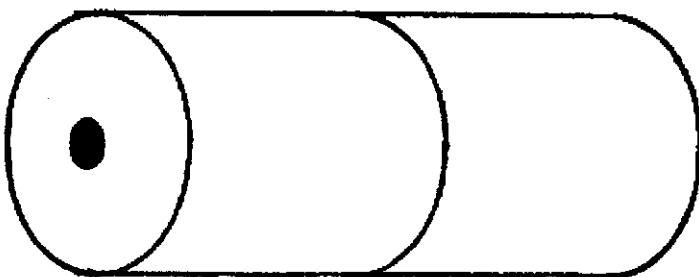
Point the kaleidoscope tube toward a light and look through the small hole. Have students spin the disk and describe what they see. Ask them to describe why the various patterns are formed.

Further Challenges:

☐ Make a larger kaleidoscope using a tennis ball can instead of film canisters and acetate sheets instead of microscope slides.

☐ Make a variety of disks for the kaleidoscope. Try using permanent markers on the acetate. Use two pieces of acetate with bits of confetti sandwiched between them.

☐ Kaleidoscopes are made of many types of materials. Design your own kaleidoscope. Determine what it would be made of and how it would be constructed. Make drawings of this instrument, label its parts, and tell how it works. If possible, construct the instrument as an independent project.



Bouncing Light

by Patsy Ann Giese

Focus:

Light is reflected from plane shiny surfaces.
Light can be reflected by several surfaces
before reaching a person's eyes.

Challenge:

Observe images formed by multiple
reflections. Count how many images can be
seen in a pair of mirrors.

Materials and Equipment:

Mirror squares	Milk cartons
Washers or coins	Tape or glue
Cardboard	Ball
Paper	Kaleidoscope
Pocket Mirrors	

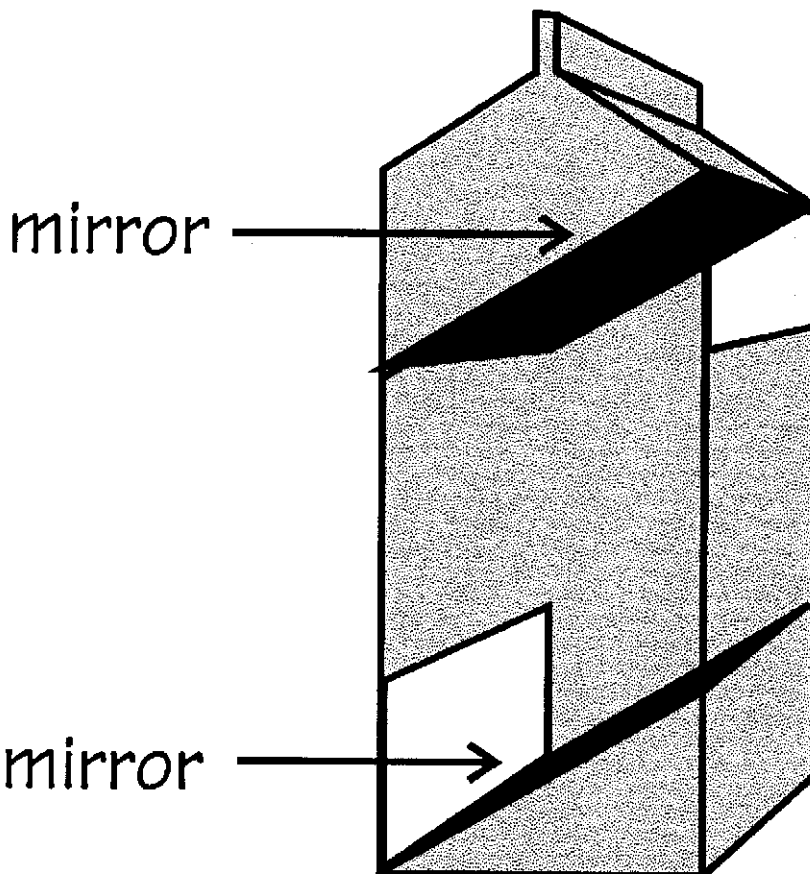
Procedure:

Have students count how many images of
themselves can be seen in two mirror squares
taped together along one edge. Images of
other objects can be counted, too. If coins are
used, have students add up the total value of
the coins they see. The number of images
seen can be increased by decreasing the size
of the angle between the mirror surfaces.

Have students hold a mirror square on their chests and then
look into a larger mirror. Have each student count how
many images of themselves they can see. Explain that
vision does not leave their eyes and vision does not bounce
off the mirrors, but instead light bounces off the mirrors
and then enters their eyes.

Ask students if they have seen the backs of their heads. For
each student who has not, use two mirrors (*one in front
and one behind*) to enable him/her to see the back of
his/her head.

A durable easy-to-use periscope can be made from plywood
pieces about 1 meter long and 15 cm wide. Instead,
students can make their own periscopes from quart milk
cartons. Into diagonal slots at 45 degrees with the top and



bottom of the periscope, place the two mirrors parallel to
each other, reflecting sides inward. Tape or glue the
mirrors firmly in place. A viewing hole needs to be cut in
front of each mirror. After predicting what they will see in
a periscope as it is placed in various horizontal and vertical
positions, have students check the accuracy of their
predictions by looking into the periscope. For example, set
the periscope horizontally with one end on a desk top so
one looks down at the desk to see the floor beyond the desk.
Explain to students that they see the various objects, not
because their vision goes through the periscope, but because
light travels through the periscope to their eyes.

Repeat this activity except use a periscope in which the
mirrors are not parallel to each other, but are still at 45
degrees at the bottom of the periscope. With this periscope,
one could look down at the desk and see the ceiling.

Further Challenges:

- ☐ Have two students play catch by throwing a ball against a wall or bouncing a ball on a floor. The students should stand in one position to play, not run after the ball. Then they must throw or bounce the ball so it hits the wall or floor midway between the two students. Have a third student mark where the ball hits. Compare two angles - the angle between the wall or floor and the path of the ball from the first student with the angle between the wall or floor and the path of the ball to the second student. The two angles should be approximately equal.
- ☐ Have students, using the law that the angle of incidence equals the angle of reflection, predict if the reflected image of an object will be seen by another student. For this activity, the positions of the student, the mirror and the object should be fixed. Repeat the activity changing the relative positions of the mirror, object, and observer.
- ☐ Have students draw pictures of the object, mirror, and observer with the rays of light included. They should show both the paths of the incoming light and the reflected light.
- ☐ Discuss how long a mirror a person needs to be able to see their full height in a mirror.. Obtain a mirror and check the answer. Cardboard can be taped over some of the mirror to get a reflecting surface the exact length of one's prediction.

Safety Tip: Warn students to not drop or knock over the mirrors. If a mirror is broken, do not let the students pick up the broken glass in their hands.

Reflections and More Reflections

by Michael J. Demchik

Focus:

Reflections in a plane mirror are virtual images that are laterally reversed. When two plane mirrors are placed together at an angle, multiple images are formed. The number of images formed depends on the angle between the mirrors.

Challenge:

How many images are formed when two plane mirrors are placed at 90, 60 and 45 degrees?

Materials and Equipment:

Index card
Marker
Clay

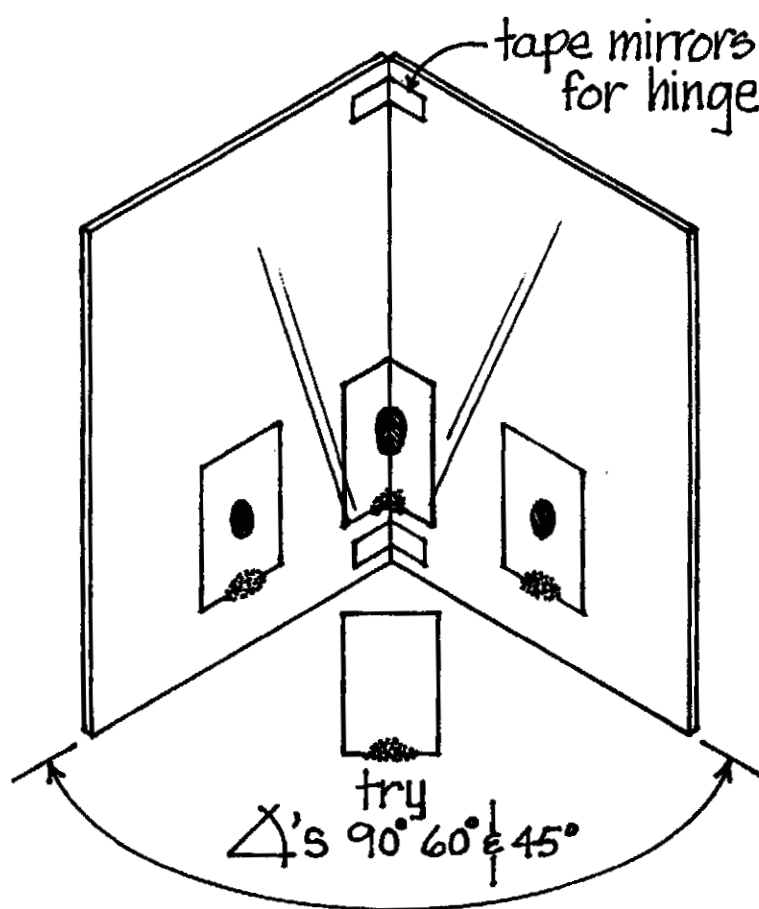
Two plane mirrors
Protractor
Tape

Procedure:

Tape together two plane mirrors to create a moveable hinge as shown. The mirrors should be able to stand freely on a flat surface. Place a dark circle on a piece of index card. Support the index card with clay in front of the mirror. Observe the results. Place the same card in front of two mirrors placed at an angle of 90 degrees. How many images are formed? Try 60 and 45 degrees. Results? Count the images formed in each case.

Further Challenge:

□ Repeat the above procedures with the mirrors arranged at various angles. Have students graph the relationship between the number of reflections and the angle of the mirror.



Straight, Curved, or Crooked?

by Patsy Ann Giese

Focus:

In any one substance, such as air, light always travels in a straight line.

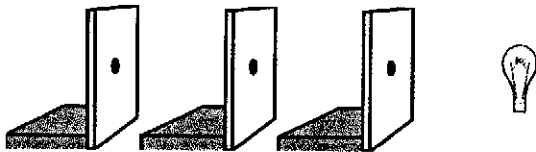
Challenge:

Observe evidence and infer that light does not curve as it travels through air.

Materials and Equipment:

Posterboard
String
Blocks of wood
Thumbtacks or glue
Candle or flashlight
Candle holder

Matches
Wire or cord
High intensity lamp
Pieces garden hose
tape
Miscellaneous objects



Further Challenges:

☐ Suspend objects, for example, a pencil, a washer, an empty food can, or a ball, from a piece of heavy wire or cord. Set up a piece of white posterboard vertically by taping or tacking it to a wall. Show students how you will hold the objects in various orientations between a light source and the posterboard. Have students draw pictures which predict how the shadow will look based on various orientations of the object relative to the light source and posterboard. Based on their pictures, have students predict what shape shadow will be made on the posterboard. Check their predictions by darkening the room, turning on the light source, and observing the shape of the shadows.

☐ Repeat the above activity, except change the distances between the light source, the objects, and the posterboard.

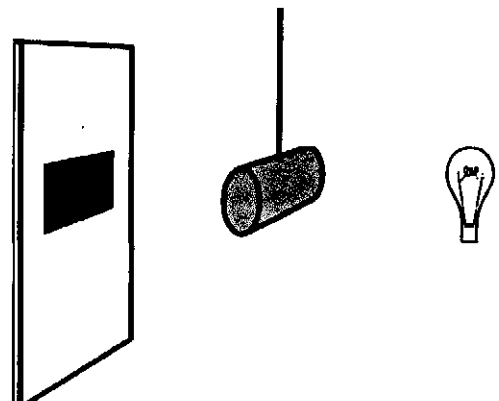
☐ Take photographs of the shadows made by several common objects. Ask students to speculate about the type object that made the shadow. Have the actual objects or pictures of the objects available for students to observe.

☐ Have a student whisper into a straight section of garden hose with another student listening at the other end of the hose. Repeat the activity with the hose curved. Discuss how sound is different from light.

Procedure:

Cut a hole in the center of five squares of posterboard. Attach each cardboard square with thumbtacks or glue to a block of wood large enough that the cardboard, when attached to the wooden base, will stand upright as shown. Darken the room. Have students stand the cards in front of a candle or flashlight, checking which positions allow the light to shine through all the holes. A taut string through the holes can aid in aligning the holes and the light source.

Have students look through straight sections of garden hose. Then have them bend their sections of hose as they continue to look into the hose. Discuss the differences between the two sets of observations.



Do You Look Strange At Lunch Time?

by Patsy Ann Giese

Focus:

Reflecting plane and convex surfaces make all things look right-side-up. Reflecting concave surfaces make close things look right-side-up, but distant things upside-down. A person cannot get close enough to see a right-side-up image of him/herself in very curved concave surfaces such as spoons. A person can see their image right-side-up in a less curved concave surfaces such as shaving mirrors.

Challenge:

Find which orientations of a knife and of a spoon give an upright image of persons looking at their reflections. Find at what distance individuals can see their image in a shaving mirror changes from right-side-up to upside-down.

Materials and Equipment:

Knives
Spoons
Shaving mirrors

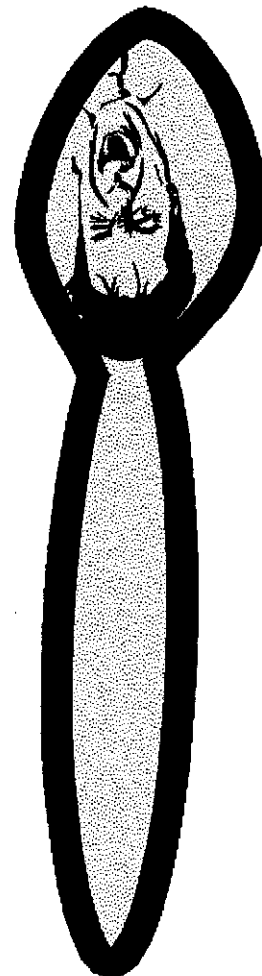
Procedure:

Each student should look at their image in the blade of a shiny knife. Repeat the activity, but with each student looking into the bowl of a shiny spoon with the handle vertically down from the bowl. Then pose the challenge to move the spoon in such a way that they see themselves right-side-up. Most students will continue to look into the bowl, rotating the spoon so the handle is horizontally to the side of the bowl or vertically up from the bowl. They need to look into the convex back of the spoon to meet the challenge. Looking at the back of the spoon, again have each student notice the changes in the shape of their image as they rotate the spoon handle up, down, and sideways.

Have one student hold a concave shaving mirror so a second student can see their own image. Have the first student back away slowly, holding the mirror level. The second student should give directions to the first in order that the mirror is oriented so the second student can continue to see the image. The second student should notice how far away the first student is when the image from the mirror inverts.

Further Challenges:

- ☐ Have students think of other shiny curved surfaces in which they can see an image of themselves. Possible answers are convex rearview mirrors, chrome car bumpers, silver goblets, steel thermos bottles, and reflectors from flashlights or headlights.
- ☐ Have students draw pictures of the shiny objects with the rays of light included, showing both the paths of the incoming light and the reflected light.



Simply Scientific Symmetry

by Patsy Ann Giesc

Focus:

Symmetry is an important property in scientific research about things as diverse as nuclear particles and human organs. Objects symmetrical about the horizontal axis are unchanged by refraction through a test tube. Objects symmetrical about the vertical axis are unchanged by reflection from a plane mirror. Multiple reflections can make the image appear the same as the object.

Challenge:

Look for symmetry in physical objects. Identify images reflected from a plane mirror as reversed left to right, and identify images refracted from a horizontal cylindrical surface as upside-down.

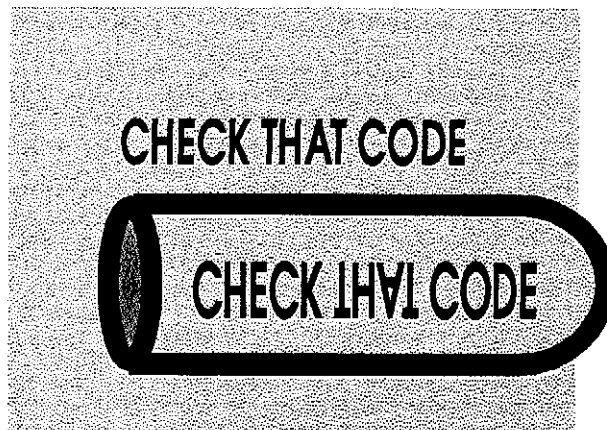
Materials and Equipment:

Mirror squares	Typing paper
Cardboard	Ribbon or Clip
Test tubes or narrow jars	Stoppers or lids
Water	Index cards
Posterboard	Paper
Magazine or pictures	

Procedure:

Fill large test tubes with clear tap water. Insert cork or rubber stoppers into the ends of the test tubes. As an alternative to the test tubes, use small clear jars, for example, ones in which green olives or spices are sold. Jars with larger diameters will not work well.

Write on index cards so that most of the letters symmetrical about the horizontal axis are one color and all other letters are another color. You could write **CHOICE MYSTERY BOOK** with the words **CHOICE** and **BOOK** in red and the word **MYSTERY** in blue. You could write **CHECK THAT CODE** with the words **CHECK** and **CODE** in black and the word **THAT** in green. Have each student place a test tube directly over the message on a card. Then each student should raise the test tube, watching the letters become out of focus. Each student should stop raising the test tube when the letters are again in focus. At this point, each student should hypothesize whether color, symmetry,



or other properties determine which letters look usual. Each student should test their hypothesis by making new cards to read.

Have students predict how they will look winking their right eye or waving their right hand in front of one mirror. Have them check which hand or eye appears to be moving in the image formed by light reflected off a mirror. Put a clip or a ribbon on a student's head. Have students check if the image of the front of their heads is reversed left to right. Using two mirrors, have them check if the image of the back of their heads is reversed left to right.

Make a clock face on a paper plate. Have students look at the image of the clock face reflected from one mirror. Ask in what ways the image is different from the actual clock face. Repeat this activity, except reflect from a second mirror the image from the first mirror.

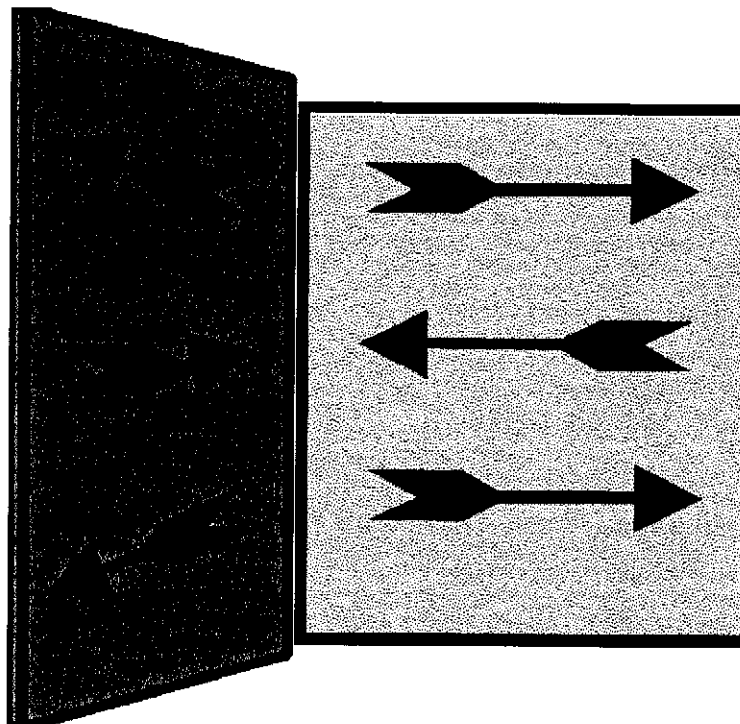
Write a message on a piece of cardboard. Have students try to read the image of the message reflected from one mirror. Ask which letters are readable and which are not. Ask what property is common to all the readable letters.

Have students compare the symmetry of letters about the horizontal axis that were unchanged by refraction through a test tube with the symmetry of letters about the vertical axis that were unchanged by reflection from a plane mirror.

Using the message and mirror from the previous activity, reflect from a second mirror the image from the first mirror. Students should observe that all the letters are readable this time.

Further Challenges:

- ☐ Write a message on thin typing paper. Turn the paper over and trace over the letters to darken them as viewed from that side of the paper. *An alternative is to write on paper over carbon paper, carbon side up.* Place the front side of the paper against a piece of cardboard, and tape the two together. Have students try to read the message viewing the backside of the paper. Then have the students try to read the image of the backside of the paper reflected from one mirror. As above, try reading the image from a double reflection of the message.
- ☐ Put the two taped mirrors at right angles to each other. *An alternate approach is to cut away one corner and the top of a cardboard box, and then glue two mirrors in the opposite corner.* Center the clock face in front of the taped edge. Have students again look at the image of the clock face. Have students wink or wave into the mirrors. Have them look at themselves wearing a hair clip, a ribbon, or an asymmetric hat. Ask if the reflections are reversed left to right.
- ☐ Have students look around the classroom and identify objects that are symmetrical about one or more axes.
- ☐ Discuss in what ways people are symmetrical and in what ways asymmetrical.
- ☐ Have students set a magazine or other large picture horizontally on a table or desk. Hold a mirror square vertically on the picture. Look at the edge where the reflecting surface touches the picture.



- ☐ Have each student draw a picture. Keeping it horizontal, the student should place a vertical mirror on one border as in the previous activity. The student should repeat this procedure, except place the mirror on another border.
- ☐ Make triangles or other shapes from several colors of posterboard or cardboard. Then have students create symmetrical designs from the pieces. Have each student challenge a second student to make the first student's design using half as many pieces on a horizontal surface next to a vertical mirror.

Safety: Warn students to not drop or knock over the mirrors. If a mirror is broken, do not let the students pick up the broken glass in their hands. It is advisable to keep a dust pan and brush handy in case of accidents.

Can You Catch Fish?

by Patsy Ann Giese

Focus:

A ray of light bends as it travels from one substance to another because the speed of light is different in different substances. Because our eyes interpret any light received as though it did not bend appearances can be deceiving from light that has passed through a refracting surface.

Challenge:

Observe evidence and infer that the apparent position of objects is different in water than in air.

Materials and Equipment:

Plastic container	Water
Aquarium	Corks
String	Washers
Metal rod or wooden dowel	Narrow tube
Coins or washers	Opaque bowls

Procedure:

See the sketch on this page. Cut a fish shape out of the bottom of a discarded plastic container, for example laundry soap bottle. Place the fish-shaped object on the

bottom of an aquarium filled with water. As an alternative, glue a fish-shaped object to a cord, and then tie the cord to a washer leaving a little string between them. Repeating this procedure, but varying the length of strings, will make the fish-shaped objects seem to be swimming at various depths. Have a student sight down a narrow tube, for example, a piece of water pipe, locating the fish-shaped object. It is easier to hold the tube steady with one's arm resting against the table. Then without moving the tube, have another student pass a metal rod or a wooden dowel through the tube. Have other students check if the rod touches the fish-shaped object. The rod will not touch, because the fish-shaped object, when sighted through the tube, appears to be in line with the ray of light that reaches the student's eyes. However, the ray of light bent as it passed from water to air.

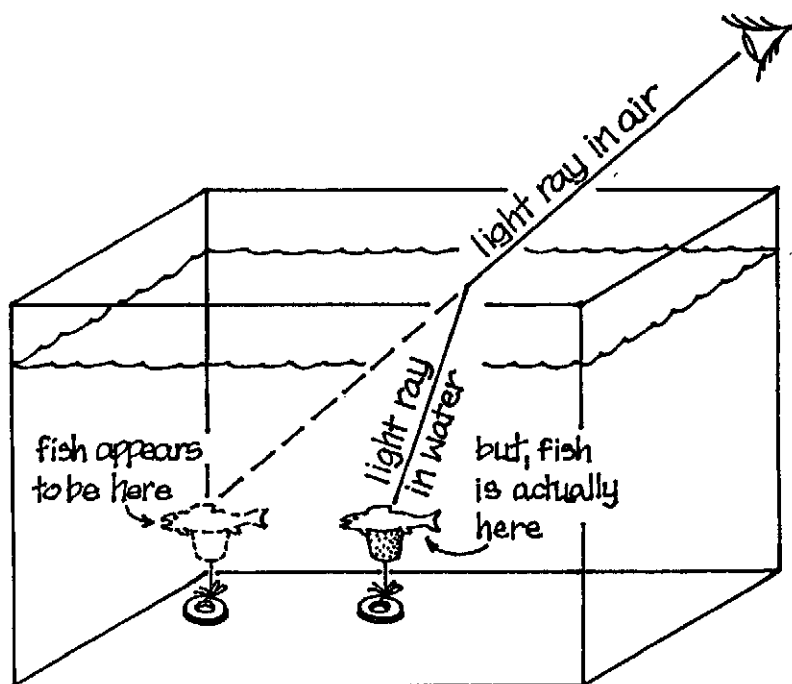
Repeat this activity, except have no water in the aquarium. Finally students will be able to catch fish.

Further Challenges:

☐ Have each pair of students put a washer or coin in a small opaque bowl, the size of one serving of fruit. (A cup, a flat pan, or the bottom of a cutoff milk carton can be used instead of a bowl.) Have one student move away from the

bowl until the side of the bowl blocks the washer or coin from sight. This student should remain there, being particularly careful to not move his/her head at all. Have the second student pour water into the cup slowly enough that the washer or coin does not move. The first student should be able to see the washer or coin again.

☐ Discuss why a pond may appear shallower than it really is to a person standing on its banks. Ask why it is important to check the depth of water before diving in?



Look Who's Got Four Eyes!

by Patsy Ann Giese

Focus:

Light is bent as it passes through curved transparent surfaces, changing the appearances of objects viewed through the refracting surfaces.

Challenge:

Observe images formed by refracted light.

Materials and Equipment:

Clear beakers	Jars
Test tubes with stoppers	Drinking glasses
Magnifying glasses	Glass marble
bowl or spherical flask	Rulers
Aquariums or clear pans	Water

Procedure:

Fill large test tubes with clear tap water. Insert cork or rubber stoppers into the ends of the test tubes. As an alternative, use small clear jars, for example, ones in which green olives or spices are sold. Have some students look at the room with a test tube in front of their eyes. They should also look at their classmates through the test tube. The test tube will make one's eyes appear elongated vertically or, at the proper distance from one's face, will make each eye appear as two eyes one above the other. Have students also describe what they saw as they looked at the room.

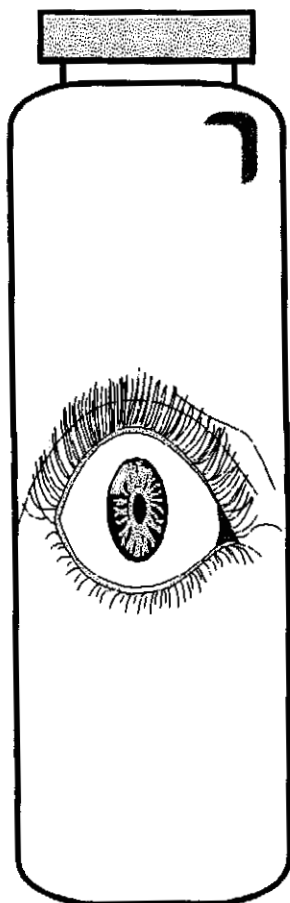
Have students look at rulers placed vertically in clear beakers, jars, or glasses of water. Ask if the width and/or the length of the rulers looks unusual? Ask if the rulers look straight? Then have students tilt the rulers and answer the above questions again. Have students move the rulers to containers with smaller diameters and then describe the change in the appearance of the rulers. Repeat this

activity, except use containers with very large diameters. Containers with larger diameters do not magnify the width of a vertical ruler as much as do containers with smaller diameters. The length of a vertical ruler is not magnified.

Empty the water out of the containers used in the above activity, and put a small washer or other weight in each. Then stand these containers in one or more aquariums of water. Clear flat-sided pans, such as bread pans, can be substituted for the aquariums. The water in an aquarium should be about 2 cm lower than the top of the shortest container so that no water flows into those containers. Repeat the above activity with the rulers. Containers with larger diameters do not reduce the width of a vertical ruler as much as do containers with smaller diameters. The length of a vertical ruler is not reduced.

Further Challenges:

- ☐ Have students look through a clear glass marble, bowl, and/or spherical flask. Look through a water drop on a window screen, window glass, or a microscope slide.
- ☐ Discuss why straight objects look wavy when seen through thick irregular glass as is found in some old windows. Discuss why the same type of objects look straight when seen through thin uniform window glass.
- ☐ Have students form images with magnifying glasses or other lenses. Have students draw pictures of the lenses with the rays of light included, showing both the paths of the incoming light and the refracted light.
- ☐ Have students think of manmade objects which require lenses. Possible answers are eyeglasses, binoculars, opera glasses, cameras, movie projectors, telescopes, and microscopes.
- ☐ Discuss lenses in the eyes of living organisms.



Liquid Lenses

by Meghan Mahoney Twiest

Focus:

The path of light waves can be controlled with two basic types of lenses, concave and convex. A lens is a tool for bending light and can be made of many different materials such as plastic, glass, or living matter. A convex lens, which is thickest in the middle, makes the beams of light passing through it converge. A concave lens, which is thickest around the edges spreads the beams of light that pass through it.

Challenge:

Make a convex and a concave lens and see what happens to images when you look through them.

Materials and Equipment:

Microscope slide
Metal washer
Newspaper

Eyedropper
Petroleum jelly

Procedure:

This intriguing activity fits well into a variety of lessons such as anatomy of the eye, use of the senses, or refraction of light through a lens. *See the sketch on this page.*

To assemble your own lenses, have the students spread a very thin layer of petroleum jelly onto the microscope slide. Next, place a washer (*one that completely fits on the slide*) on top of the layer of jelly. Now the washer won't slide around. After the washer is secure, have the student put about a dozen drops of water into the center of the washer and spread it around with the dropper until water is touching all the sides of the washer. A concave lens is formed when the layer of water is thickest around the edges and thinnest in the middle. When the lens is held over a newspaper, the print will appear much smaller than it really is. This is because the light rays are spread out as they pass through the water.

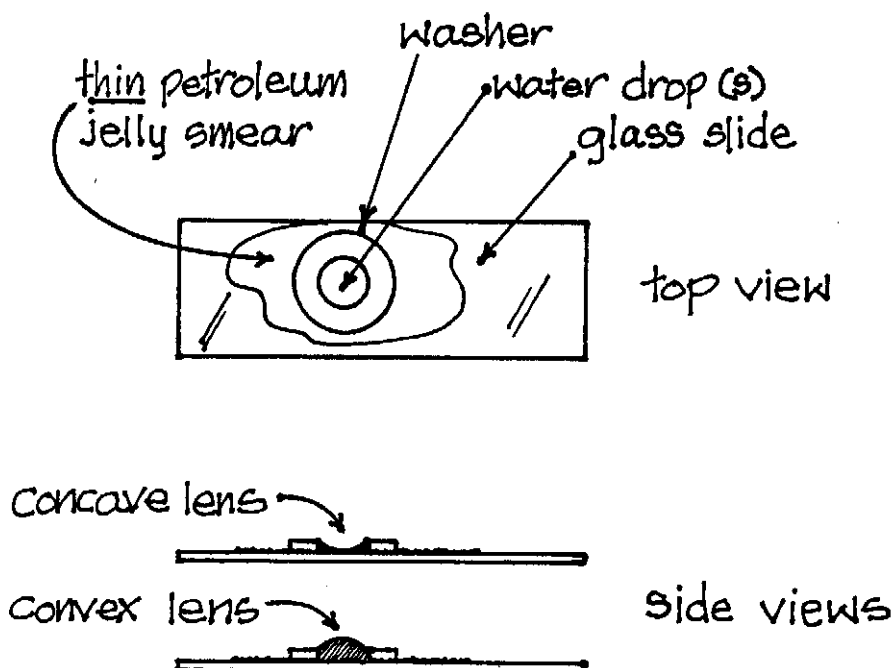
To make a convex lens, place a couple of dozen or so more drops of water inside the washer until the water "heaps" up in the center. The surface tension of the water forms this heap as the water molecules adhere to each other. When using this lens to look at the newspaper, the print will be magnified.

Further Challenges:

- ☐ Shine a flashlight through the lenses onto a piece of paper and see what differences you will discover.
- ☐ Have an optometrist come into the classroom and explain types of lenses and how they are used to correct eye problems.

Reference:

Mallison, G.G.; J.B. Mallison, D. Brown, J.W. Knapp, and W.L. Smallwood. (1981) *Science: Understanding Your Environment*, Morristown, N.J.: Silver Burdett Company.



Demagnification

by Michael J. Demchik

Focus:

Demagnification is a topic often left out of the study of light.

Challenge:

What kind of a lens produces demagnification? What relationship exists between distance and demagnification? Do compared distances provide measures of demagnification?

Materials and Equipment:

Depression slide or concavity slide (3" x 1")
Newspaper print
Ruler

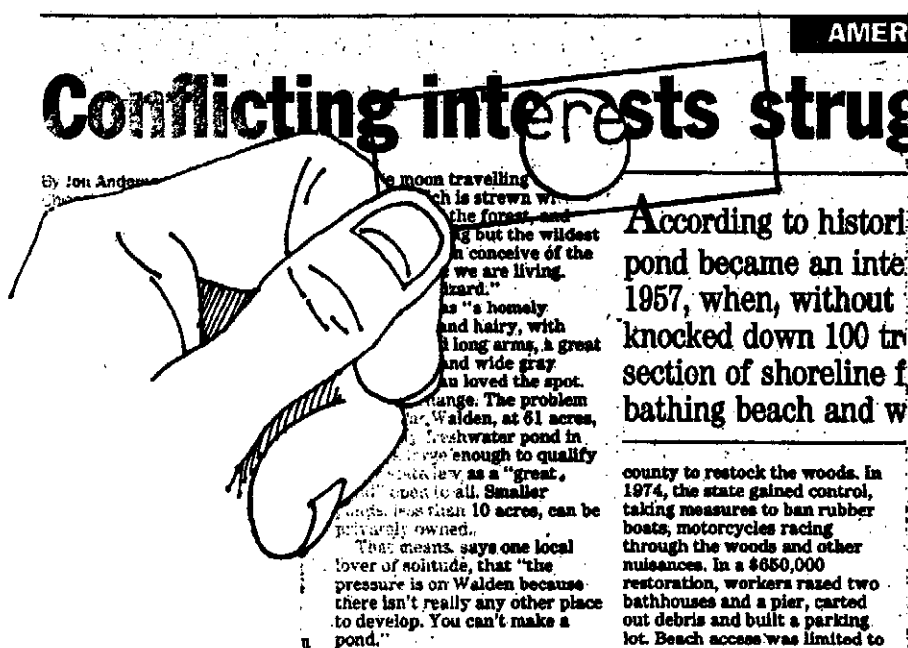
Procedure:

Select a newspaper that has a large headline. Find a letter "C" which just fits into the depression. Use the letter "C" for your investigation. Start with the concave surface

toward you and place the letter under the slide. Move the concave surface away from the surface of the letter and observe that the letter gets smaller. Select several points to view the letter. At each of these points, measure the distance from the slide to the letter. Then estimate and record the apparent size of the letter as it appears in the circle as viewed through the slide. Measure and record the distance from the letter to the lens. Record the data in chart form. Plot the distance away against the demagnification (*apparent size*). Determine the relationship between the two variables.

Further Challenges:

☐ Put a penny into a graduated cylinder partially filled with water. Look down the tube and place your finger where you think that the penny is located. Vary the depth of the water and then compare the data. See if you can determine the relationship.



How Lenses Turn Us Upside-Down

by David R. Stronck

Focus:

Light rays are bent as they travel through lenses. When light travels through double convex lenses, the image created beyond the focal point is inverted.

Challenge:

Discover what lenses do to light rays.

Materials and Equipment:

A very dark room	Birthday candles
Modeling clay	Matches
Magnifying lenses	White index cards

Procedure:

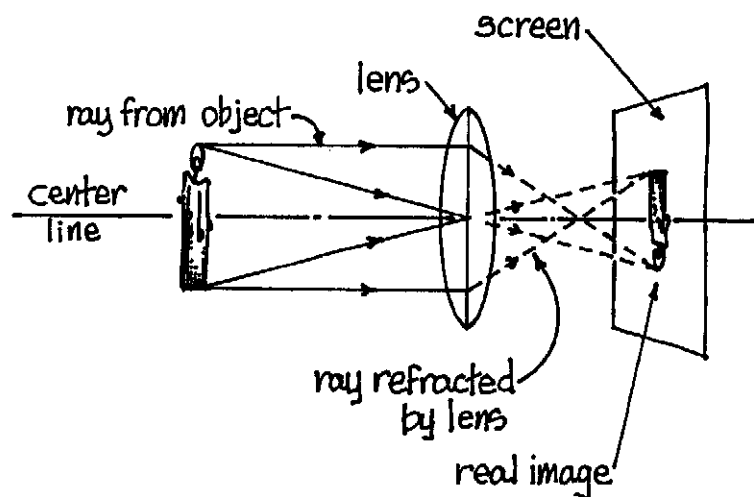
Ask the children to predict what light rays do when they pass through a magnifying lens. Invite them to see what happens by doing the following:

Organize the students into teams of three persons. The first student has responsibility for the candle. The second student takes the magnifying lens. The third student holds the white index card. They should set up their materials as shown on this page. Small pieces of modeling clay may be used to hold the candle, lens, and index card in place.

Light the candle. Darken the room. Hold the magnifying lens between the candle and the white card. Move the magnifying lens slowly back and forth between the candle and the white card. Observe the image of the candle flame on the white card.

Direct students to answer the following questions about the image: Is the magnifying lens close to the flame when the image of the flame appears to be upside down? Where do you move the magnifying lens if you want a larger image of the flame? Can the magnifying lens be placed to present such a small image that there is no image at all? Can the magnifying lens be placed to produce an image that is not inverted?

Discuss with the students how the rays of light pass through the lens and sharply bend their direction when they leave the lens. The result is an image that is inverted. Students can draw a diagram showing a light ray from the top of the flame entering the top of the lens but leaving at such an angle that it is at the bottom of the image. Similarly a light ray from the bottom of the flame enters the bottom of the lens but leaves at such an angle that it is at the top of the image.



Further Challenges:

☐ Use flashlights in place of candles. To mark the top of the flashlight's ray of light, tape a small piece of cardboard over the part of the flashlight's glass window. Do similar activities as described above.

☐ Use a ruler to measure distances between the magnifying lens and the image. Use these measurements to find the focal point where all of the light rays will converge at one spot. Measure the height of the image on the white cardboard card. Describe how the height of the image changes as the magnifying lens is moved. Have the students compare their measurements of similar observations.

Where Do Flowers Get Their Colors?

by Mildred Moseman

Focus:

Chromatography can be used to show the different components of pigments in plants. Chromatography is used primarily in chemistry as a means of separating and analyzing mixtures of chemical compounds by the use of an absorbing material. It works because each chemical in a mixture moves at a different rate in the upward flow of the alcohol. Different compounds are absorbed and found in separate sections of the paper.

Challenge:

Hold up a purple blossom from a petunia. What gives it its color? How could we use chromatography to find out?

Materials and Equipment:

Red geranium	Purple petunia blossoms
Rubbing alcohol	Toothpicks
Paper towel (<i>coffee filter</i>)	Drinking glass
Mortar and pestle (<i>spoon & lid</i>)	

Procedure:

Have children crush torn bits of the blossoms in a small amount of alcohol with a mortar and pestle. Do this with various blossoms in separate operations.

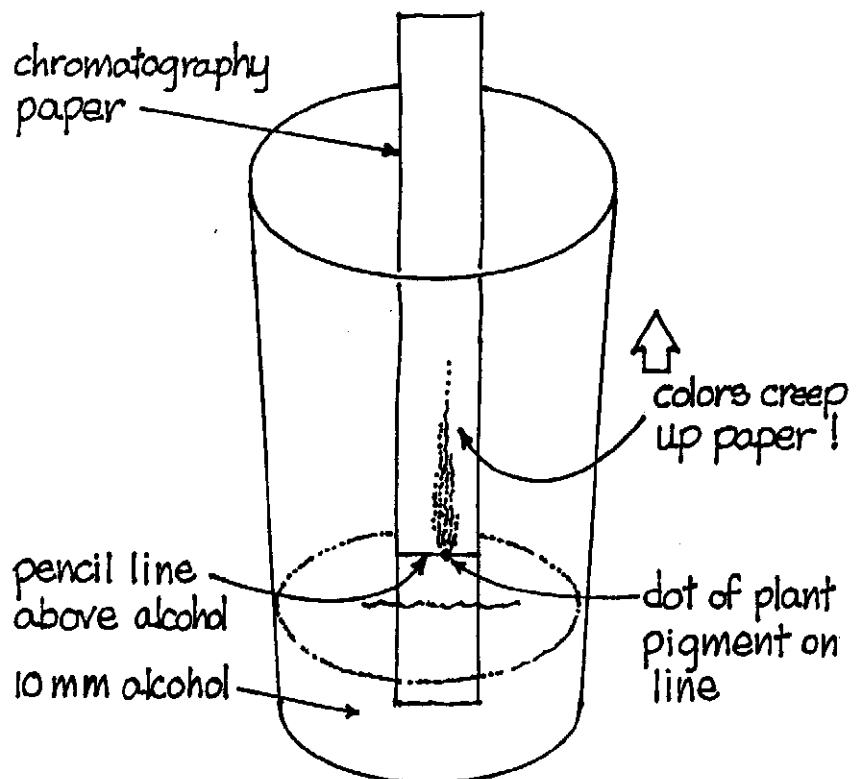
Cut several pieces of paper towel, coffee filter paper, or chromatography paper into 15 cm x 1 cm pieces. Draw a horizontal line across a piece of paper near the bottom of the paper with a pencil.

With a toothpick, place a dot of the plant pigment on the center of the line. Place the end of the paper in a drinking glass in which a small amount of rubbing alcohol has been placed. (*See the sketch on the following page.*) The alcohol must not touch the mark. The strips may be taped to the outside of the glass.

Have children keep track of color sequence, band widths, travel time, and distance traveled of each blossom. Excitement mounts when colors begin to creep up the paper. This can also be done with green leaves.

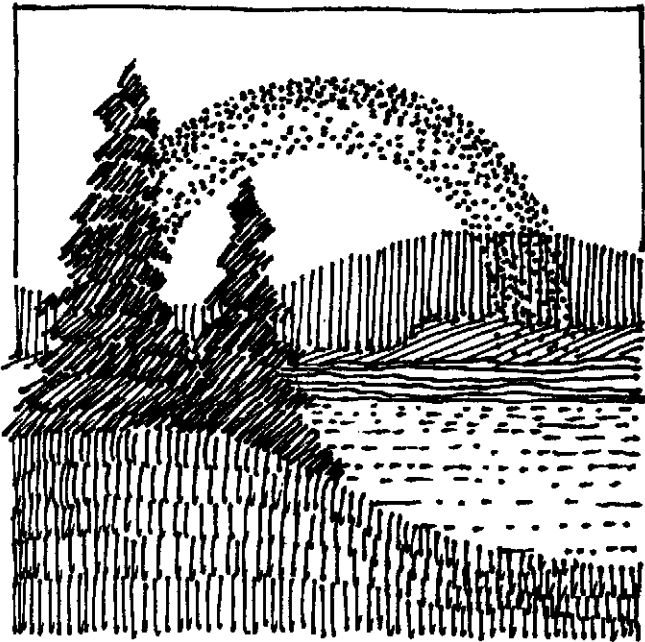
Further Challenges:

- ☐ What are some other possible uses for chromatography? How are plant pigments formed?
- ☐ Why do some colors rise higher than others?
- ☐ Does chromatography work with various kinds of markers, inks, or paints?



Rainbow Physics

by Judith McKee



a rainbow as seen from Earth...
appears half-hidden

Focus:

A rainbow is a portion of a complete circle which is not visible because of the horizon. Occasionally, a rainbow can be viewed in its entirety from an airplane.

Challenge:

Demonstrate a complete rainbow using a horizon line which obscures the total configuration.

Materials and Equipment:

Crayons or marking pens
Circle template
White construction paper

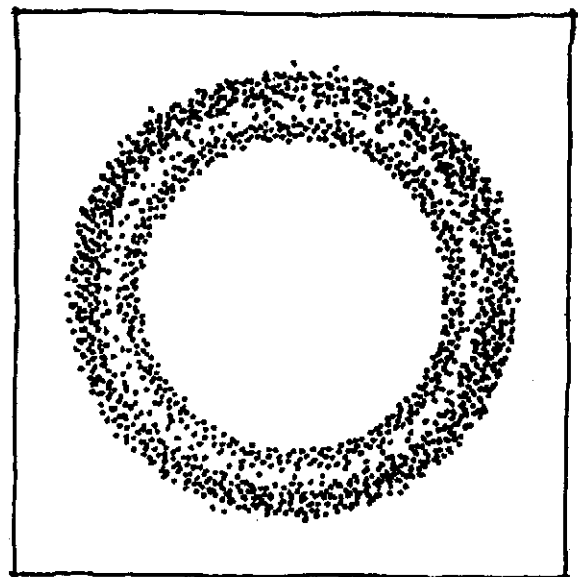
Procedure:

Use a template outline of a single circle as a starting point for the rainbow. Then with the acronym **ROY-G-BIV** (red, orange, yellow, blue, indigo and

violet) as a guide for ordering colors, have the children make their own rainbows. Remember that violet is the shortest band of the light in the spectrum and red is the longest. Then make a horizon cover so that the rainbow is viewed as we usually see it. This is a good opportunity for creativity to flourish as each scene will, hopefully, be unique.

Further Challenges:

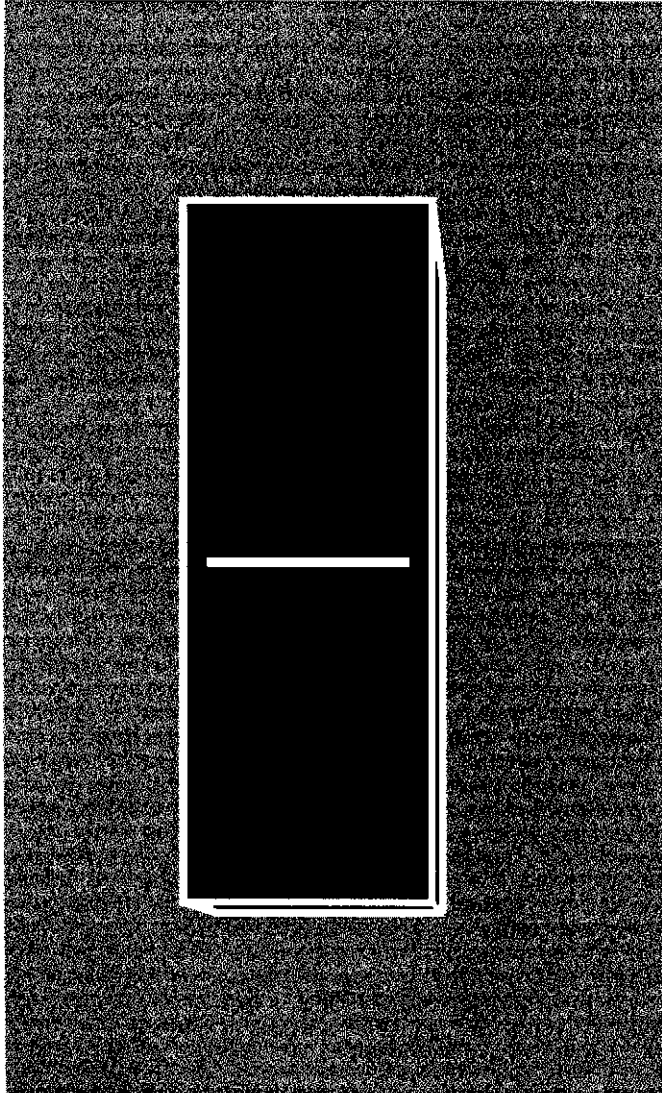
- ☐ By looking at the completed rainbow circle, the children can easily see that the violet band in the rainbow is shorter than the red one.
- ☐ Experiment with light (sunlight or an artificial light source) and various prisms to make rainbows. Note the length of the band of color in the spectrum.
- ☐ Discuss why the rainbow curves into a circle shape.



a rainbow as seen from an
airplane... is a complete circle

Diffraction Slits

by Gerald Wm. Foster



Procedure:

Cover a desk or table with newspaper. Spray one side of a microscope slide with black paint. Allow to dry which takes approximately five minutes.

Take a razor blade and make a fine line through the paint. Hold the slide with the line up to a light and look for bands of light and dark.

Further Challenges:

- ☐ Make several lines to see what happens. Try making the lines at different distances from each other to see what happens.
- ☐ Try different kinds of light sources. For example: light from a window, fluorescent light, incandescent bulbs that have a vertical filament as well as those that have a horizontal filament.
- ☐ Use colored cellophane to cover the slide to see if certain colors will block out certain parts of the spectrum.
- ☐ Try other ways to diffract light: hold two fingers close together and look between them at a light source. Try nylon stockings or some other finely meshed materials that allow light through and look at a light source. Use finely meshed window screen to produce a spectrum.

Focus:

Producing a light spectrum by diffracting light.

Challenge:

Finding various ways to diffract light.

Materials and Equipment:

Microscope slides
Spray paint (flat black)
Single edged razor blade
Newspaper

Polarized Light

by Gerald Wm. Foster

Focus:

Diffraction of light using cellophane and polarized film.

Challenge:

Students will create different colored designs by making slides using polarized film and cellophane.

Materials and Equipment:

Cardboard slide covers

Polarized film

An assortment of cellophane tape

An assortment of cellophane packaging

Slide projector and screen

Scissors

Procedure:

Cut a piece of polarized film to fit into a slide cover. Seal it shut with a piece of tape.

Cover one side of the prepared slide with strips of cellophane tape. Put the strips of cellophane at different angles and overlap them. The way the strips are placed will create the design. The type of cellophane will create the intensity of the different colors.

Put the slide into a slide projector. With the projector light on, rotate a larger piece of polarized film in front of the projector lens. The rotation creates different patterns and different colors of the spectrum.

Further Challenges:

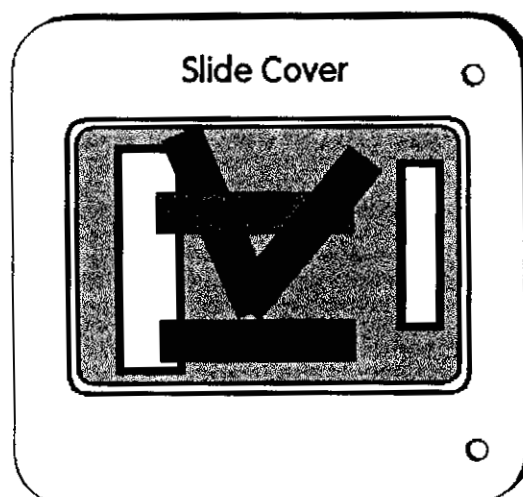
☐ Use pieces of cellophane wrapping on top of an overhead projector and rotate a piece of polarized film above the cellophane as the image is projected on a screen.

☐ Make a slide that contains a drop of water or oil in the center.

☐ Try different kinds of sunglasses on the overhead projector. As the piece of polarized film is rotated,

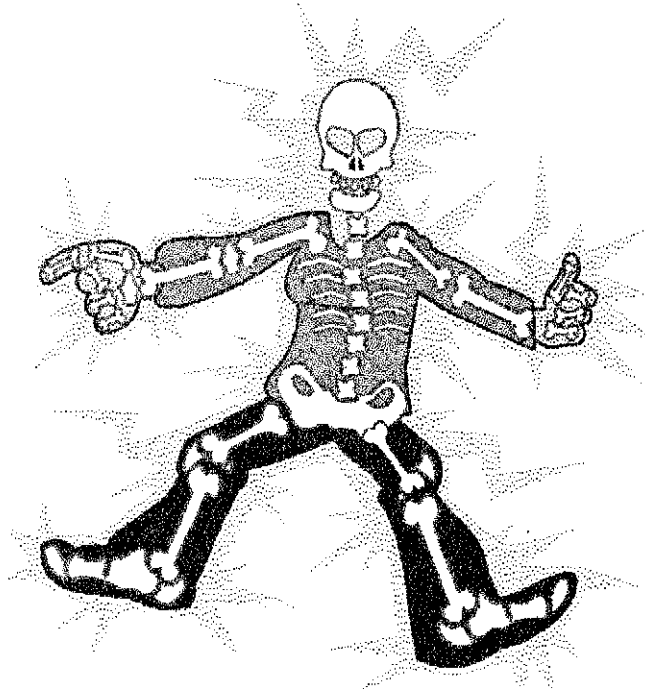
determine which sunglasses contain polarized lenses and to what degree they contain the polarizing element.

☐ Play music in the background and let students create different moods with the colors projected on the screen as they rotate the polarized film in front of the projector lens with the beat of the music.



CHAPTER 4

ELECTRICITY FROM STATIC TO CIRCUITS



Dancing Dolls

by Meghan and Mark Twicst

Focus:

This experiment demonstrates how oppositely charged particles attract each other.

Challenge:

Make paper dolls dance through the use of static electricity.

Materials and Equipment:

glass, (apx. 12 x 25 cm.)	thick books
silk cloth	tissue paper
Scissors	

Procedure:

Abstract concepts such as electrical charges can be explained more easily through the use of concrete examples which the students can handle and explore.

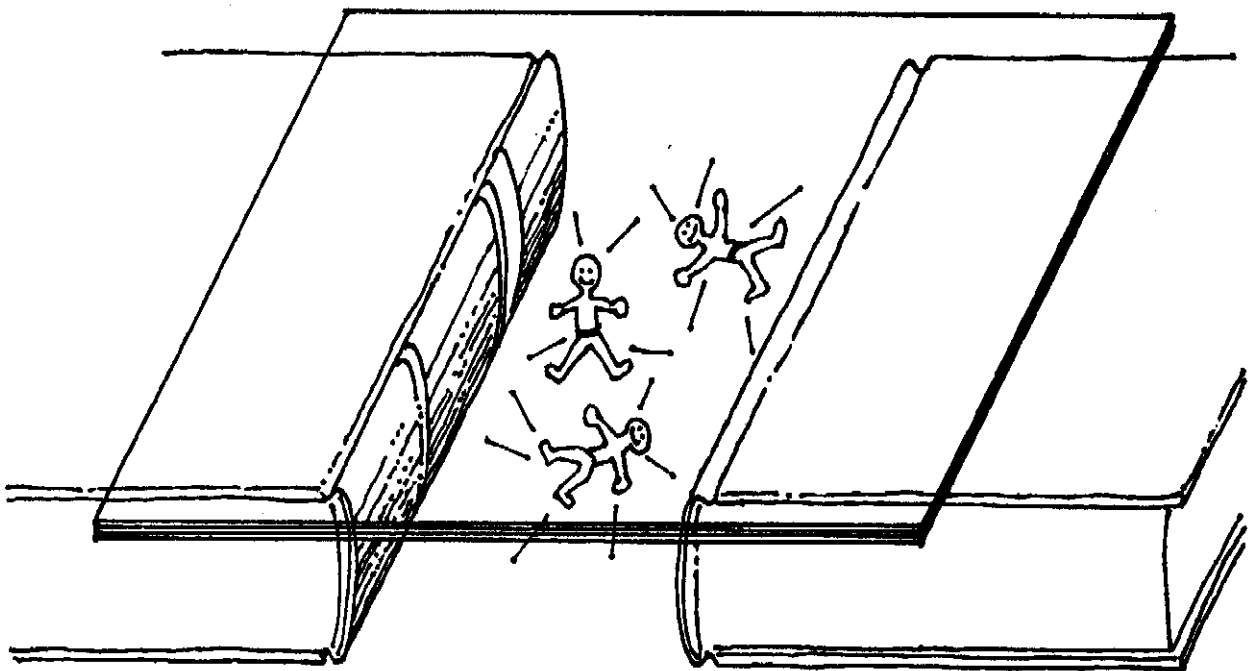
See the sketch on this page. First, on a high counter, visible to all students, place the two thick books about four inches apart. Have each of the students cut paper dolls out of the tissue paper. Allow them to put their names on their dolls so that they can easily be identified. Then place the

dolls on the table between the books. Ask the children to think of ways to make the dolls move, without touching them. After the students shake the table and blow on the dolls, tell them you know of another way to make the dolls move. Place the glass over the dolls so that it is propped on top of the two books. Next, rub it vigorously with the piece of silk. The dolls will dance up and down between the glass and the table top.

When the glass is rubbed with the silk, the silk takes some of the electrons from the glass and becomes negatively charged. The glass having lost the negative charge subsequently becomes positively charged. The paper receives an induced negative charge from the glass and is attracted to it.

Further Challenges:

- ☐ A hair comb can pick up small pieces of paper after running the comb through your hair, using this same principle.
- ☐ Does this activity work better on days with low or high humidity? Why?



Charge Your Classroom

by Yvonne A. Johnson

Focus:

Observation is the major emphasis in this series of activities for electrostatics. Children should be encouraged to experiment in finding other ways to produce electricity.

Challenge:

Through a series of related experiments children will discover that static electricity is produced when you create friction.

Materials and Equipment:

Comb
Stream of water
Electrician's tape

Inflated balloon
Cereal

Procedure:

A note to teachers before beginning work with electrostatics: These experiments work best in winter when it is cold and dry. If you comb your hair to charge the comb, the hair should be clean, dry, and free of creme rinse and hair spray.

Have students bring a comb near small bits of paper. Note motion, if any. Next have them run a comb through their hair several times and bring it near small bits of paper. Note if any pieces of paper are picked up or moved. Again have students run the comb longer and harder through their hair and bring it near small bits of paper. Discuss with students why static electricity causes the movement seen. Ask students if they can share any examples of electrostatics in their experience.

Further Challenges:

☐ Run a comb many times through your hair and bring it near a stream of water

coming from a faucet. How does the electrical charge in the comb affect the water stream. (See the drawing below.)

☐ Bring an inflated balloon that has been rubbed near small bits of paper.

☐ Touch an inflated balloon that has been rubbed to a wall.

☐ Bring an inflated balloon that has been rubbed near to someone's hair.

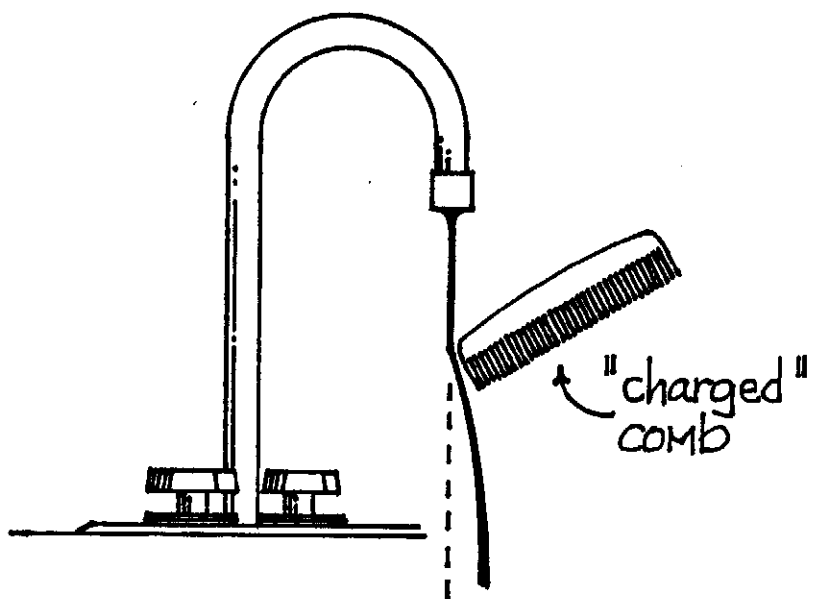
☐ Rub a comb to charge it and bring it near cereal.

☐ Flip and shake your blanket hard when you go to bed.

☐ In a dark room, sharply pull electrician's tape away from the roll.

☐ Why was fabric softener developed to be used for doing laundry?

☐ Why do gas trucks have a chain that touches the ground?



Let the Sparks Fly

by Richard Bollinger

Focus:

Static and current electric charges are essentially the same. Electrical charges are found in everything. Static electric charges can be easily generated by friction.

Challenge:

How can you demonstrate the similarity between static and current electricity?

How can static electricity be produced?

How can an object be tested for the presence of electrical charges?

Materials and Equipment:

Balloon	Clay
Sharpened pencil	Index card
Aluminum pie pan	Rubber bands
Assorted items (see Activity 3)	Fluorescent bulb
Plastic sheet	

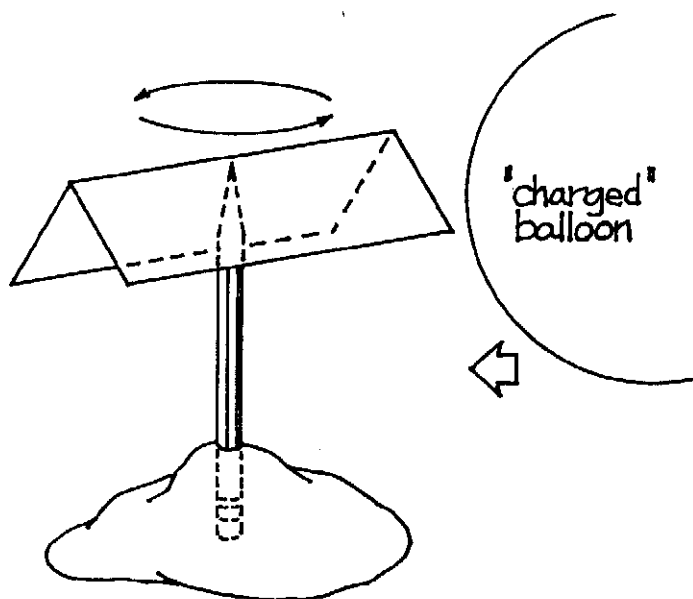
Procedure:

Start the lesson by pointing out a balloon stuck to the wall. Ask students to explain the cause of the balloon sticking. You may remove the balloon at one point, rub it on your hair, and stick it back on the wall.

After a student states the cause as static electricity, ask students if they can see the electricity in the balloon. Many students have seen this demonstrated but have little or no understanding of static electricity. Ask the students if electricity is dangerous to touch? How can we discover if the balloon is charged with electricity?

Activity One: Constructing a tester.

Construct the tester as shown on this page. Place a sharpened pencil, eraser first, into a ball of clay so that the pencil is able to stand erect. Fold an index card in half the long way and balance it upon the pencil point so that it is able to pivot around. Bring the charged balloon(s) near



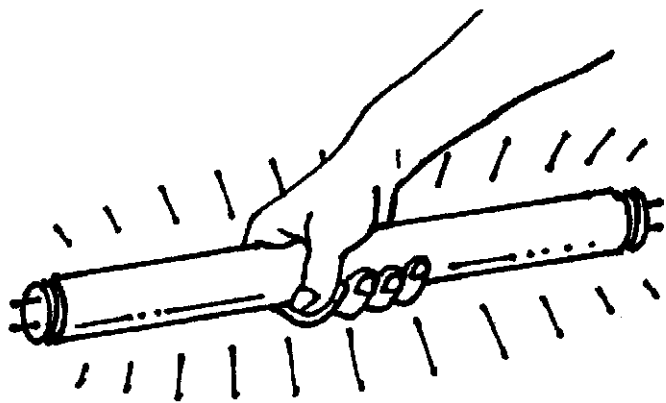
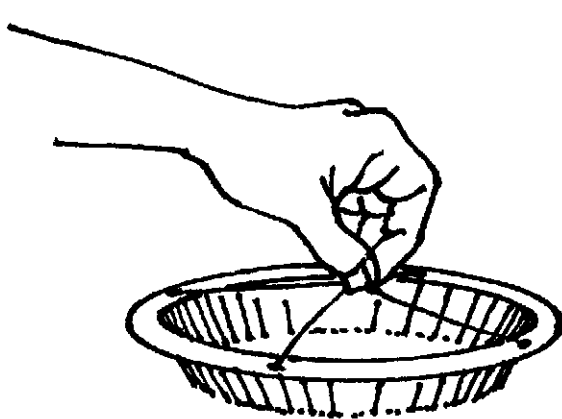
the index card and watch how it attracts the card causing it to spin around.

Activity Two: Is the Balloon charged?

Construct an electrophorus by placing two rubber bands across an aluminum pie pan in an "X" shape. Holding on to the rubber bands as a handle, rub it across a sheet of plastic. (See the drawing on the next page.) Experiment using several types of plastic until you find the kind that produces the strongest charge. Being careful not to touch the pie pan with your hand. (The charge in the pie pan will enter your body.) Bring it near the metal ends of the fluorescent tube. (The tube may even be dead.) The fluorescent tube will briefly glow demonstrating that you are generating "real electricity." Bring the charged pie pan near the electricity tester and see if the tester can indicate the presence of an electric charge. Movement of the card shows that the "index card electricity tester" is working.

Activity Three: Testing Other Materials.

Begin by asking students to describe the common factors when the balloon and pie pan were charged. (Both were rubbed.) Encourage students to experiment with a variety of materials by rubbing them against each other or a soft cloth. Such materials may include rubber or plastic combs,



plastic pens, plastic rulers, wax candles, crayons, small glass drinking glasses, soda straws, pieces of rubber hose, small pieces of paper, plastic bags, scraps of wool, silk, fur, and cotton cloth.

Have students test which materials will produce static electricity, as indicated on the "index card static electricity tester". Materials such as wood and metals, which do not produce electrical charges, should also be included.

Further Challenges:

☐ Does the direction in which you rub cause any change in the charge?

☐ Why do many pieces of clothing stick to each other when they come out of the dryer?

☐ What causes the spark to come out of your fingertip after you walk on carpeting?

☐ What would we have to do to keep the fluorescent tube lit for a longer period of time? (*Keep the charges coming.*) This is an excellent lead-in for the topic of current electricity.

☐ Investigate the causes of lightning.

Electric Circles

by Stephen C. Blume

Focus:

Although children can define a circuit after studying a textbook, they need concrete experiences with a battery, bulb, and wire to really understand the concept of circuit.

Challenge:

How many ways can you get a bulb to light using a battery, a bulb, and one wire? Where does the electric current flow when the bulb lights? What are the special places on the battery that must be touched to get the bulb to light? What are the special places on the bulb that must be touched to get the bulb to light?

Materials and Equipment:

D-cells (batteries)
Copper wire
Flashlight bulbs

Procedure:

Each child is given a battery, a bulb, and one wire. Tell the children to get the bulbs to light as many ways as they can. By manipulating the materials in different ways, the children will light the bulb. Eventually, one or two children will get the bulb to light. The other children will copy the arrangement to get their bulbs to light. Ask the children what special places on the battery have to be touched to get the bulb to light. Also, ask them what special places on the bulb must be touched to get the bulb to light.

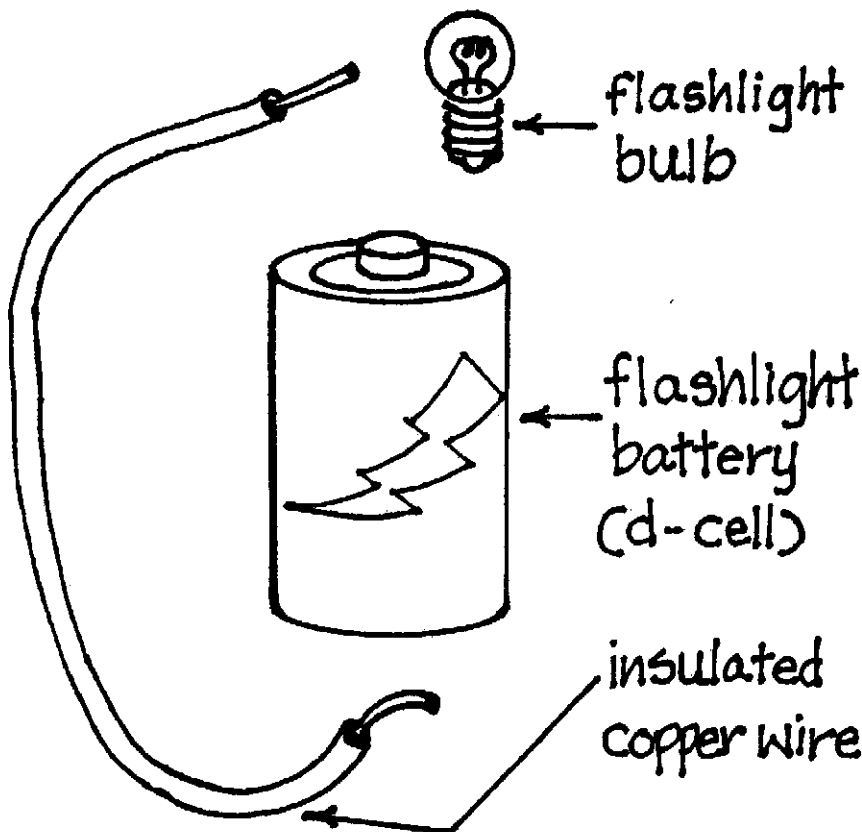
Note that the dry cell battery has two special places. The top of the battery is the positive terminal, and the bottom of the battery is the negative terminal. Electrons flow from the negative pole to the positive pole of the battery when connected in a circuit. The bulb has two special places that must be connected to the dry cell to light the bulb. The

silver tip on the bottom of the bulb and the gold threads on the side of the bulb are the two special places that must touch or be connected by a conductor to the two poles of the battery.

Tell the children to find other ways to light the bulb. If necessary give the children hints such as "I wonder if the bulb will light if the battery is upside down," "Try to light the bulb with the bulb lying down on the battery," or "Are you touching all the special places on the battery and bulb?"

Have the children describe how the electricity flows through their circuit. Then, have the children draw the arrangements that lit the bulb.

Next, give the children another wire so that they have a battery, two wires, and a bulb. Tell them to get



the bulb to light with their materials, but the bulb cannot touch the battery this time. Again, give them hints as necessary, have them describe how electricity flows through their circuit, and have them draw the arrangement that lighted the bulb.

Further Challenges:

□ How many bulbs can you light with one battery and one wire? What happens to the brightness of the bulbs when more than one bulb lights up? How can you explain what happens to the brightness?

□ How many bulbs can you light with one battery and two wires? Get a partner and try to light as many bulbs as you can without any of the bulbs touching the battery. What happens to the brightness of the bulbs when more than one bulb lights up? How can you explain what happens to the brightness?

□ What do you think will happen if you connect two batteries to one bulb? Try it with your partner. What happens to the brightness of the bulb? How can you explain what happens to the brightness of the bulb?

References:

Friedl, Alfred E. (1986) *Teaching Science to Children: An Integrated Approach*. New York: Random House.

Hone, E.B., J. Alexander, and E. Victor. (1971) *A Sourcebook for Elementary Science*. New York: Harcourt Brace Jovanovich, Inc.,

Liem, Tik L. (1981) *Invitations to Science Inquiry*. Lexington, MA: Ginn Press.

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Build A Heavy-Duty Circuit Board

by Charles Nease

Focus:

Students need hands-on experience in setting up and manipulating series and parallel circuits. They need materials which facilitate systematic comparisons and explorations. The common practice of using a loose assortment of sockets, bulbs, wires, and batteries, however, may promote confusion rather than understanding. Using a circuit board may provide beginners with an unambiguous arrangement of these items.

Although commercial circuit boards are available, they tend to be both costly and fragile. Fortunately, teachers can make less expensive and far more durable ones with parts obtained from hardware stores or supply catalogs.

Challenge:

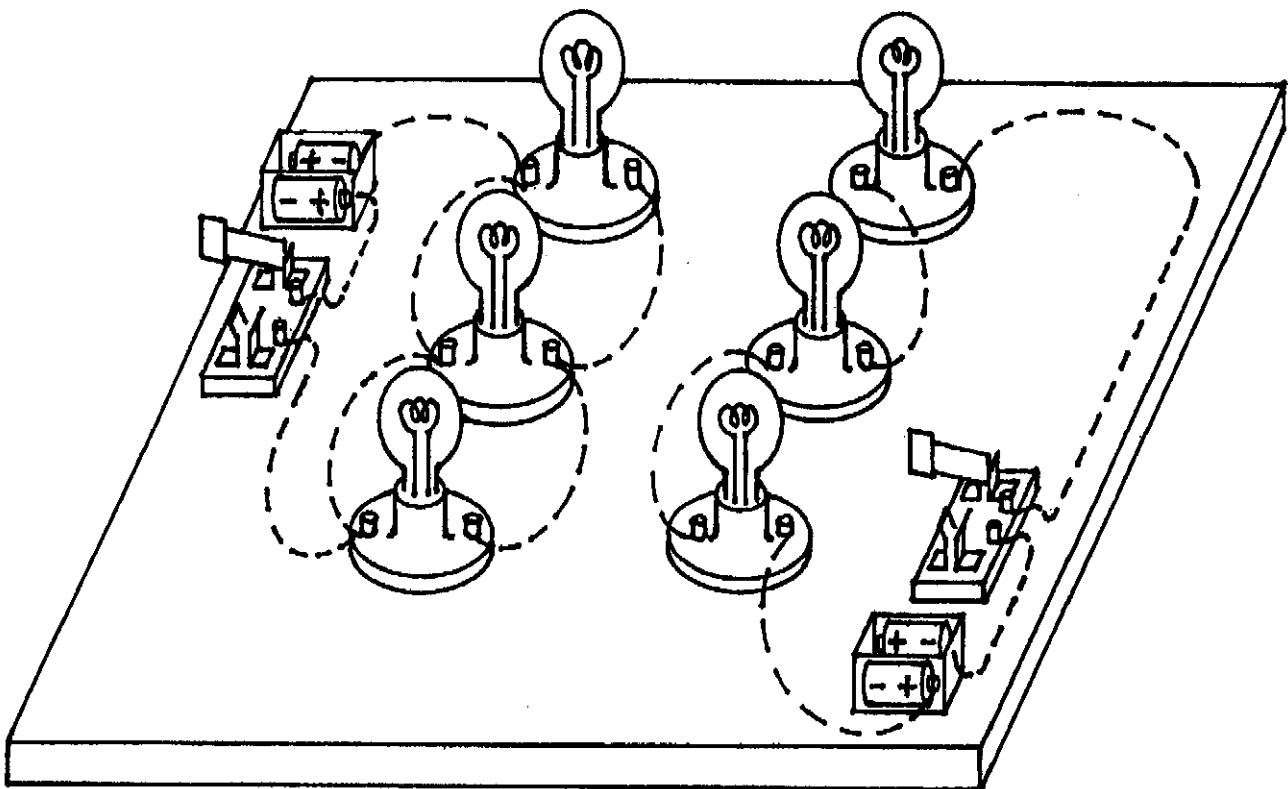
Complete the series and parallel circuits by adding the missing wires. Then make as many comparisons as possible between the two types of circuits.

Materials and Equipment:

- 1 masonite board (30 x 30 x 0.7cm)
- 2 batteries
- 4 D - cells
- 2 knife switches
- 6 lamp sockets (*miniature, screw base*)
- 6 3-volt dry cell lamps (*screw base*)
- 1 roll bell wire (*18 gauge annunciator wire*)
- 20 machine screws (632 x 3/4")
- 20 washers
- 20 lock washers
- 20 nuts
- 5 rubber bumpers
- 1 drill with bit
- 1 wire stripper 1 screwdriver
- 1 illustration of series and parallel circuits (*optional*)

Procedure:

Build circuit boards as illustrated below for each group of students. All components (*battery holders, sockets,*



switches) may be fastened to the masonite board with screws. Holes drilled slightly smaller than the diameter of the screws will make this part of the construction easier. To protect the working surface from the machine screws protruding from the bottom of the circuit board, mount five rubber bumpers underneath the board. Place one in each corner and one in the center.

Have students work in groups of two or three to add the wires as shown by dashed lines in the illustration. They will need instruction in using the wire stripper, and a clear illustration of the two types of circuits may be helpful. Since they may inadvertently set up short circuits, instruct them to turn off the switches and ask for help if any wires start to heat up. When the circuits are complete, ask these questions:

- What differences do you see with the switches off? With them on?
- What do you think is causing this difference?
- Have the students unscrew one bulb in each circuit. Now what differences do you see? What is causing this?
- Show me the paths the current is taking now.
- Which circuit is like those in your house or apartment? How can you tell?
- How do you know that the batteries are not causing the differences in brightness? How can you prove whether they are or not?

Have the students draw and label the two circuits in their notebooks. After the hands-on experience, these drawings will be meaningful for review purposes.

Further Challenges:

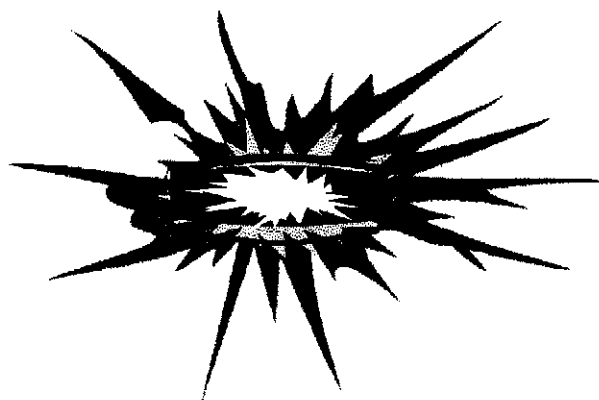
- ☐ Have students use two U-shaped pieces of wire to bypass one bulb in each circuit, but this time do not have them fasten the wires down. Have them make comparisons and trace the paths of the current. *(The short circuit on the parallel side will cause the wires to heat up, so remind them to remove the new wires when this occurs.)*

- ☐ Let them connect the batteries and bulbs in any configuration they wish. Again, have them trace the current paths to explain what is happening. *(Repeat the warning about short circuits.)*

- ☐ After they have become proficient at tracing current paths, give them a socket with a bulb, two single pole, double throw switches, a battery box and wire or alligator clips. Have them set up a circuit with two-way switches. *(The clips will save time and wire. This activity may require dozens of trials.)*

Safety Tip:

If you are using Alkaline batteries, be careful that students do not allow short circuits to stay connected for extended periods of time. Alkaline batteries may overheat, leak potentially harmful chemicals, or explode. Regular carbon batteries will not last as long, but may provide a safer substitute for students who may misuse them.



Electric Sparklers

by Stephen C. Blume

Focus:

Children can better understand how a light bulb works by being given the opportunity to create a working model of a light bulb. Then, by performing investigations with their light bulb, they can better understand electrical resistance.

Challenge:

How can you make a model of a light bulb using batteries, two wires, a lump of clay, and your special wire? What do you observe happening to the filament of the model light bulb just before it glows? How can you explain why the wire glows? How many batteries does it take to get your "bulb" to light? What happens if you use too many batteries with your model light bulb? How do the number of batteries affect the brightness of the model light bulb? How does the length of the filament wire affect the brightness of the model light bulb? What do you observe when you use steel wool as the filament of your light bulb? How can you explain what happens to the steel wool?

Materials and Equipment:

D-Cell batteries
Copper wire
Stranded galvanized steel picture hanging wire
(or #32 nickel chromium wire)
Steel wool
Clay
Masking tape
Metric ruler

Procedure:

The children are assigned to groups of 4 or 5 students. Each group is given 4 fresh D-dry cells, two 40 cm lengths of copper wire, a small lump of clay, masking tape (to hold batteries together), a metric ruler, and 10 cm of stranded picture hanging wire. If the children are using nichrome wire, give each group three batteries. Tell the children to make a model of a light bulb using the materials. Direct them to use only one strand of the galvanized wire. Also, tell them that the length of the filament between the copper wires should be 1 cm in length. If the children have

trouble getting started, it may be helpful if you pass around an unfrosted bulb for them to look at and discuss how it is constructed. See the sketch at the end of the activity.

Eventually, a group will get the bulb to light. Other groups will observe the arrangement and also get their bulbs to light. Ask the children to describe what they observed when the circuit was completed. Also, ask the children how they can explain why the special wire glowed.

Next, tell the children that they are going to determine how the number of batteries affects the brightness of the filament. Have each group make certain that the length of their filament is 1 cm. Then, tell the children to try lighting the bulb with different numbers of batteries starting with one battery and continuing until they use six batteries. When the activity is completed, ask the children how many batteries it took to get their "bulb" to light and what happened if too many batteries were used.

Now ask the children how they would determine the effects of the length of the filament wire on the brightness of the bulb. Ask questions until the children decide that they will need to use different lengths of filament wire and keep the number of batteries constant throughout the experiment. After completing the activity, ask the children questions such as "What happened to the brightness of the bulb as the length of the filament wire was increased?" "What was the longest length of filament used and the bulb still lit?" and "How can you explain how the length of filament affects the brightness of the bulb?"

To culminate this series of activities, have the children use a small ball of steel wool as the filament of their model light bulb. This activity is especially effective in a darkened room. The children will observe "sparklers" as the steel wool burns. Ask the children what they observe and how they can explain why the steel wool sparkles.

Further Challenges:

□ What happens to one strand of steel wool if it is placed between the copper wires? What do you think will happen to two strands of steel wool twisted together? How many strands of steel wool will it take before you can make a

model light bulb using steel wool as the filament? Try it with your group.

□ Can you think of any other kind of wire that might be used to make a model light bulb? Do you think that a very thin copper wire would make a good light bulb filament? Do you think that a thin piece of aluminum foil from a gum wrapper would work as a light bulb filament? Try them with your group. If these metals do not work as a light bulb filament, can you think of another electrical use for them?

□ Ask students "What is a fuse?" Using what you have learned, how would you make a fuse? What material could be used for a fuse? Try using a thin strip of aluminum foil from a gum wrapper as a fuse in a circuit with your group.

References:

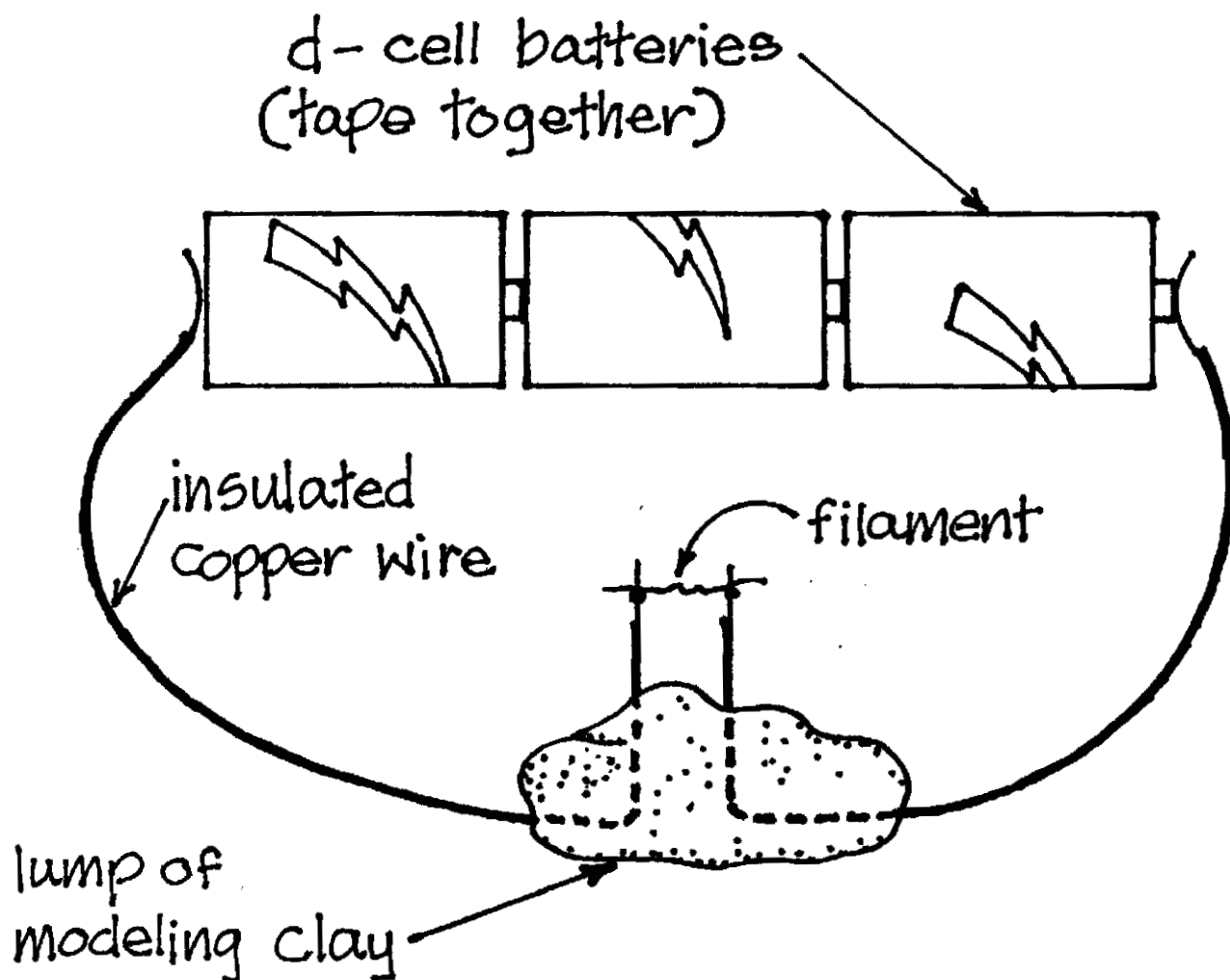
Education Development Center, EDC. (1966) *Batteries and Bulbs*. St. Louis, MO: McGraw-Hill.

Liem, Tik L. (1981) *Invitations to Science Inquiry*. Lexington, MA: Ginn Press

Lowery, Lawrence F. (1985) *The Everyday Science Sourcebook*. Palo Alto, CA: Dale Seymour Publications.

Safety Tip:

The wires used as filaments or fuses will become quite hot. Students should be warned not to touch them or let them come in contact with combustible materials.



Breaking the Electric Connection

by Carole Kuchinsky

Focus:

A fuse will cause a break in an electric circuit when the amount of current flowing through it exceeds a certain limit.

Challenge:

What happens to the fuse when placed in the series circuit? How does steel wool act like a fuse? Is it possible to construct the series circuit so the "fuse" does not cause an open circuit?

Materials and Equipment:

batteries and holders
switches
Fine steel wool

plastic coated wire
light bulbs and holders

Procedure:

The electrical system in any building can cause a fire if not constructed properly or used safely. A fuse is a safety device used to protect an electric circuit against overloading. Wires within a circuit that become overheated can cause a fire. The fuse prevents this by melting and therefore breaking the circuit when an unsafe amount of current is flowing.

Set up a series circuit using three batteries, a switch and a bulb. (See the drawing on this page.) Test the circuit to make sure it works. Remove the end of one wire from the end of the battery holder. Attach another wire to the end of the battery holder. Connect the two free ends of wire together with several strands of steel wool as shown in the diagram. The steel wool is the fuse. Alligator clips fastened to the end of these wires will make fastening the steel wool easier.

Close the switch. Observe the steel wool closely. Describe what happened to the "fuse"

when it was placed in the circuit. The electric current will be conducted by the steel wool. The heat energy generated will cause the steel wool to reach its "combustion" temperature: it will burn briefly, the circuit will be broken, the current will no longer have a continuous path to follow, and the bulb will no longer light.

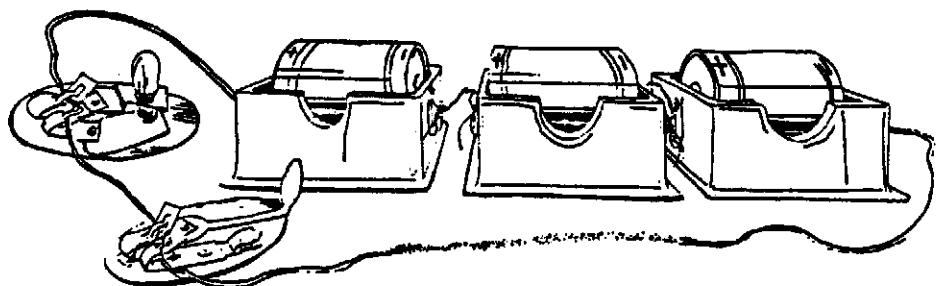
In many houses today, fuses have been replaced by circuit breakers. A circuit breaker serves the same function as a fuse; it breaks an electric circuit. The difference is in the method. The circuit breaker contains a bimetallic strip which will bend when overheating occurs and, in bending acts like a switch. It opens the circuit.

Further Challenges:

- ☐ How is a circuit breaker a safety device in an electric circuit?
- ☐ Repeat this experiment using a parallel circuit.
- ☐ Make a list of electrical hazards in your home and make some suggestions for eliminating them.
- ☐ This activity is taken from The Franklin Institute's Museum-To-Go Electric Circuits activity kit.

Safety:

This device should be constructed on a noncombustible surface.



The Electrical Penny Pitcher

by Ginny Petrie

Focus:

Certain materials will conduct electricity. However, no matter how well a material conducts electricity, a complete circuit must be in evidence to allow electrons to flow and produce an effect.

Challenge:

Children will build a maze from aluminum foil that is connected on only one end of each parallel path to a dry cell. See the drawing below. When a penny is tossed in such a way as to complete the circuit on the maze, a bulb that is wired into the circuit will light. This "toy" demonstrates the principle of completed circuits to youngsters who have made the game for themselves.

Materials and Equipment:

Stiff cardboard	brass brads
Aluminum foil	Rubber cement
light bulb and bulb holder	plastic coated wire
D-Cell and holder	pennies or steel washers

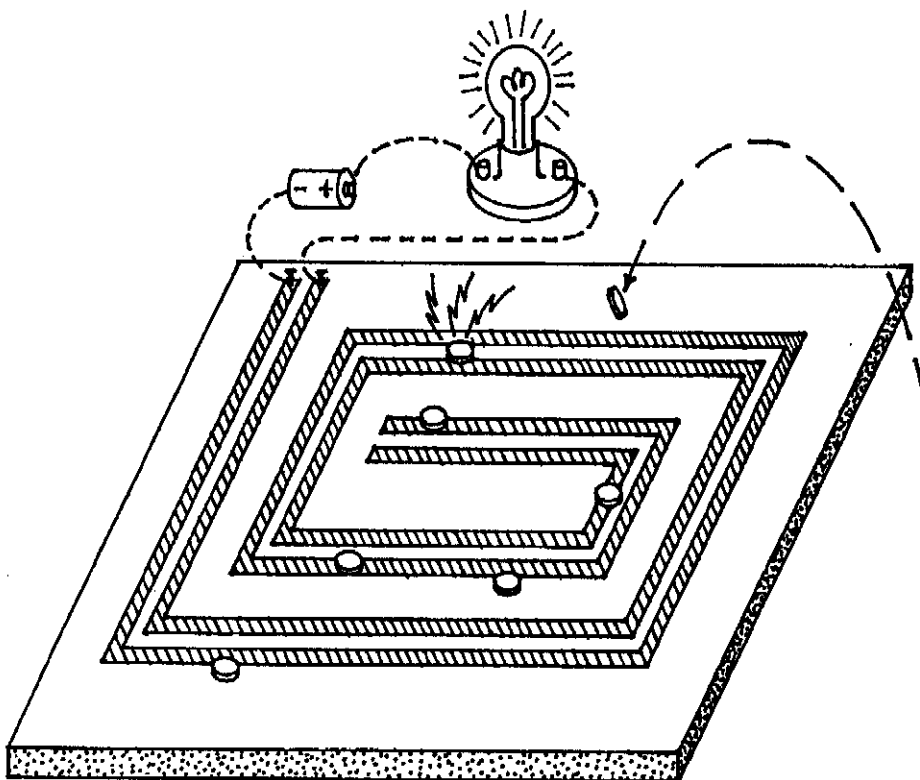
Procedure:

Construct a penny pitcher yourself to demonstrate to the class before challenging them to construct one. Have students make a pattern out of paper first to try out. Strips should be about 1/4" wide. Once the pattern is acceptable, then transfer to foil. This can be done by putting the pattern on top of a large piece of foil and tracing it out. As an alternative, the pattern could be traced onto the cardboard with pieces of foil placed onto the pattern marked cardboard. (Younger children find this second method to be easier.) If you transfer the pattern to the cardboard, you next glue the foil to the cardboard wiping away any excess glue.

At one end of the maze, where the parallel patterns come to the edge, stick in two brass brads. Connect wires, battery and bulb as shown in the diagram. Take a penny and move it along the maze to make sure that proper contact is made. Students are now ready to play with the game and test their skill at throwing pennies.

Further Challenges:

- ☐ Try making the maze with other materials. Does it work as reliably? Does it work better?
- ☐ Use other materials for pitching: other coins, paper clips, washers, etc.
- ☐ What games and game rules can you invent for the Penny Pitcher.



Circuit Puzzles

by Rose West

Focus:

Students will construct and use Circuit Puzzles from easily obtained materials. Circuit puzzles can be used to learn or study content in science or tied into other subject areas.

Challenge:

To build a circuit puzzle using information from various sources.

Materials and Equipment:

File folders	Brass fasteners
Plastic coated wire	Bell wire
bulbs	Battery
bulb holder (optional)	battery holder (optional)

Procedure:

The students do research to select a topic for their circuit puzzle. They might select countries and their capitals, authors and their books, elements and their symbols, math problems and solutions, etc. Using the front of the file

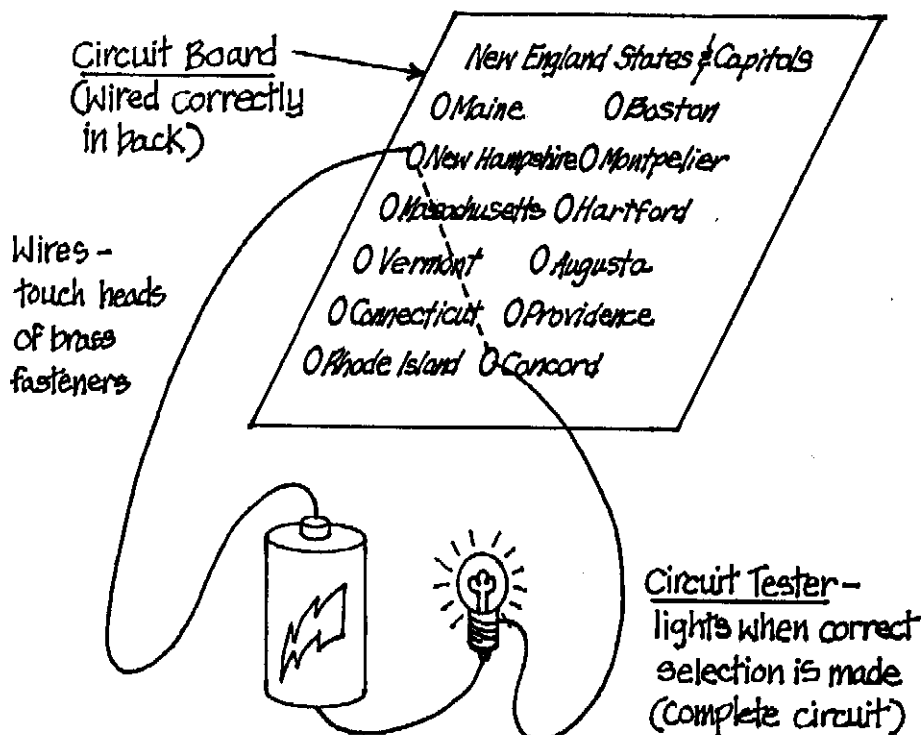
folder, the student will list, for example, the countries of Europe on the left side. On the right side they would list the capitals of the countries in jumbled order.

Beside each name the students insert a brass fastener. On the back of the cover a wire is attached to the brass fastener by a country. The other end is attached to the capital of that country.

A circuit tester can be made by attaching a wire to one end of a battery and the other end to the side of a bulb. Attach a second wire to the opposite end of the battery. A third wire is attached to the end of the bulb. When wires two and three touch the circuit is closed and the bulb will light. (See diagram on this page.)

If the circuit puzzle is constructed correctly, the light bulb will light when wires two and three are touched to the brass fasteners of a country and its capital.

By using this method, students do research for social studies, language arts, math, science, or foreign language. In this way they are able to learn about circuits and increase their knowledge of other areas of science or other subject.

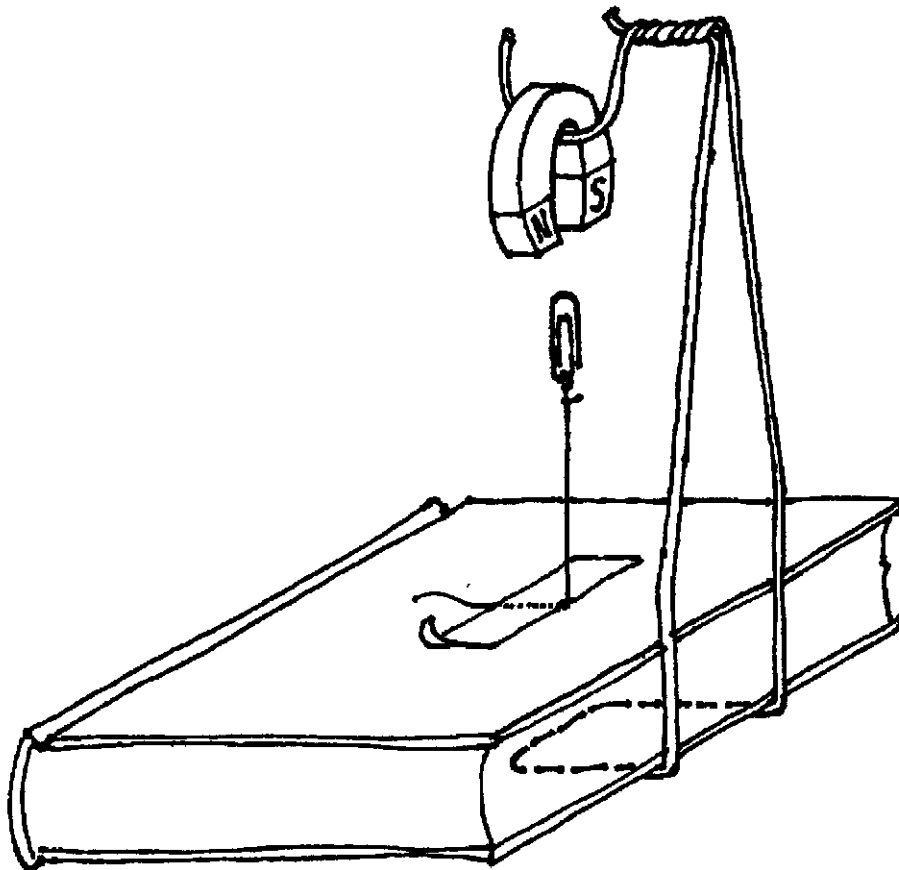


Further Challenge:

- ☐ Show the circuit puzzle to other classes and get input from them.
- ☐ Do circuit puzzles for each class.
- ☐ Help others do circuit puzzles.

CHAPTER - 5

ELECTRICITY FROM MAGNETISM TO GENERATORS



Household Attractions

by Sandra K. Abell

Focus:

Discovering real life applications of classroom concepts is an essential step in the learning process. In this activity students have an opportunity to connect school with home as they look for uses of magnets in their world.

Challenge:

How many different ways can you find magnets being put to use at your home?

Materials and Equipment:

Data sheet (as shown below)

Procedure:

Have your students guess the number of magnets they think they will find in use around their homes. They should also predict which room (e.g. *kitchen, bedroom, garage*) will be richest in magnets. After they collect their data at home, summarize class findings on a chart like the one shown below.

Further Challenges:

☐ The time will now be ripe to explore magnet applications in other settings. Field trips and phone calls to various work places (*police station, TV studio, garage, power plant*) combined with personal interviews and tours should give your students a better idea of the many practical uses of magnets.

<i>Room</i>	<i>Use</i>	<i>Number of Magnets</i>
<i>Kitchen</i>	<i>Can opener</i>	<i>1</i>
<i>Kitchen</i>	<i>Cabinet latches</i>	<i>10</i>
<i>Family Room</i>	<i>Stereo speakers</i>	<i>2</i>
<i>Basement</i>	<i>Wall stud finder</i>	<i>1</i>
<i>Bathroom</i>	<i>Medicine Cabinet</i>	<i>2</i>
<i>etc.</i>		

Be sure that students compare their results to their predictions.

Magnet Magic

by Sandra K. Abell

Focus:

Children enjoy sharing their discoveries with others. A magic show is a delightful vehicle for applying and communicating findings from magnet investigations.

Reference:

Freeman, M. (1967) *The Book of Magnets*. New York: Four Winds Press.

Challenge:

Can you create a "magic" act that uses magnets to do the magic?

Materials and Equipment:

Assorted magnets
Cloth (to use as a magic scarf)
Paper clips
Classroom junk box

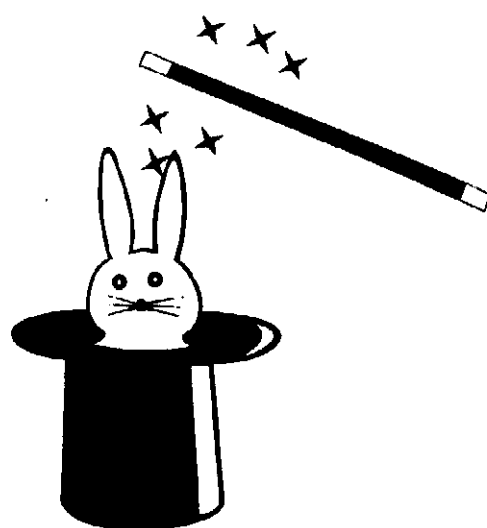
Procedure:

After your students have had plenty of time to discover which items are attracted by magnets, tell them they are going to use magnets to perform some "magic." Share with them your own magnet magic trick: start with a pile of paper clips on the table. Cover them with your magic scarf and say some magic words. Raise the scarf and "What do you know!", the paper clips have disappeared! (Of course, you were palming a magnet that attracted the paper clips when you lifted the scarf.)

Challenge your students to figure out your "magic" and then allow them, individually or in pairs, to design original magnet magic acts. All of the tricks can be put together into a traveling magic show to be performed for other classes in your school.

Further Challenges:

- ☐ Try to figure out the "magic" involved in a particular magician's tricks. Then attempt to do the trick yourself.
- ☐ How can you use magnets to create a treasure hunt in your classroom?
- ☐ Design puppets that operate magnetically and use them to perform a puppet show for some friends.



Strength Detector and Other Inventions

by Sandra K. Abell

Focus:

Inventive thinking is one way to encourage creativity in your room. In this activity and its extensions students will start to look at magnets in new ways and put them to new uses.

Challenge:

Can you design an invention that will determine the relative strength of different magnets?

Materials and Equipment:

Assorted magnets
Classroom junk box

Procedure:

Throughout earlier magnet investigations no doubt your students have noticed that not all of the magnets in the class collection are equal in strength. Take a class vote on which magnet they think is weakest and strongest. Then present the invention challenge to small groups who will work cooperatively to solve it. *(They will probably need several class periods to perfect their products.)* The solutions can be named and then presented and tested during a class Invention Convention.

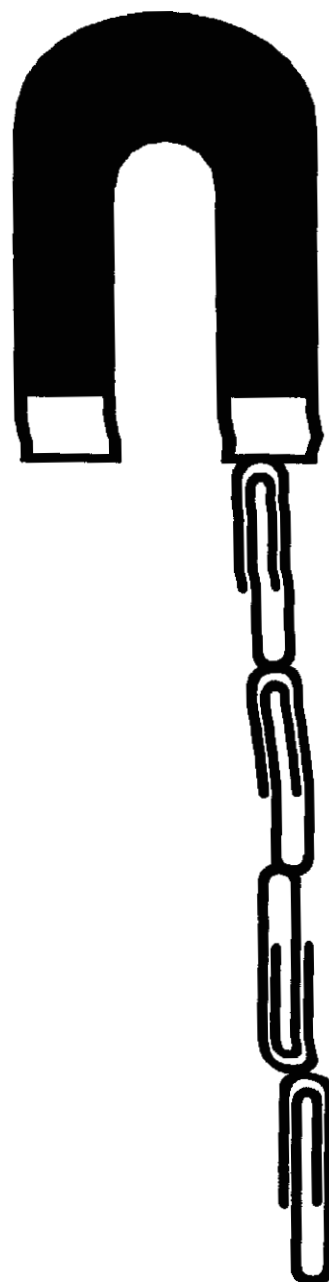
Further Challenges:

- ☐ Invent a game in which magnets are an essential part.
- ☐ Invent a Rube Goldberg contraption to do a simple task *(for example, stapling your papers)* in which magnets are used for one or more steps. The invention can be drawn or actually built, depending on time and materials available.

References:

Keller, C. (1944) *The Best of Rube Goldberg*. Englewood Cliffs, NJ: Prentice Hall Inc.

McCormack, A.J. (1981) *Inventors Workshop*. Belmont, CA: David S. Lake Publishers.



Making A Paper Clip Float

by Meghan Mahoney Twiest

Focus:

Forces of magnetism travel through the air and through other matter.

Challenge:

Make a paper clip float in mid air with the magic of magnetism.

Materials and Equipment:

Paper clip
Wire coat hanger
Thread

Magnet
Heavy books
Tape

Procedure:

Either as an introduction or a follow up activity, this demonstration captures the students' attention. Begin by designing support apparatus as shown on this page. Bend the coat hanger as shown and use a book to hold it in an upright position. With your support now in place hang the magnet from the top. Next tie the thread to the paper clip and tape the other end of the thread to the top of the book so that there is at least a one inch space between the magnet and the paper clip. Presto! The paperclip "floats" in mid air!

Ask the students to use what they have learned about magnetism to explain why the magnet appears to be floating in the air. They should be able to tell you that there is actually a force that is present between the magnet and the paper clip that is drawing them together. Ask the students what might happen if the string were cut? You may want to try it and find out.

How strong is the magnetic force that is drawing the paper clip toward the magnet? The force passes through the air without any problem. What other matter will the magnetic force pass through? Try other materials such as paper, foil, wax paper, wood (*a pencil perhaps*), cellophane, etc. Have students predict what materials will be able to break the force between

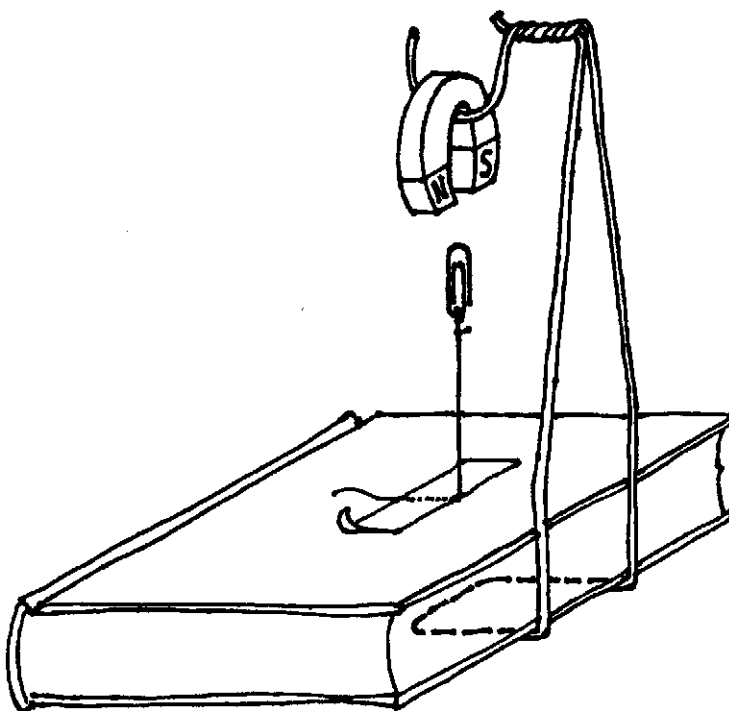
the magnet and the paper clip. Then have them experiment and record the results.

Further Challenges:

- ☐ See if the force of various magnets is equal by measuring the maximum distance between the paper clip and each magnet.
- ☐ How many magnets does it take to support a chain of paper clips?
- ☐ Reviews on magnetism can be made even more fun by letting them "fish" for review questions. This can be done by putting paper clips on review questions and using a pole with a magnet hung on it to fish for the questions. This can be a challenging way to reinforce the concept of magnetism!

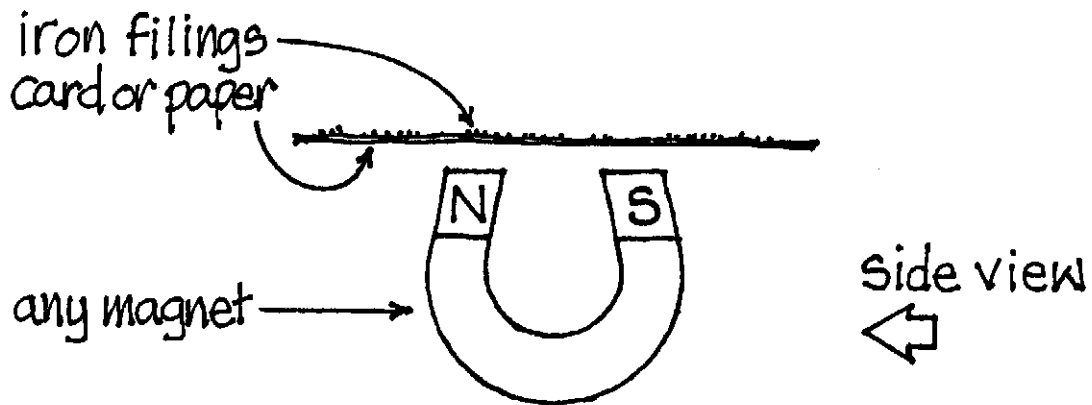
Reference:

Baker, T. (1961) *Baker Physical Science Packet for Elementary and Junior High School*. Holland, Michigan: Baker Science Packets.



Magnetic Patterns

by Judith McKee



Focus:

Magnetic lines of force are lines in which the magnetic force reaches out from a magnet. A magnetic field is the space around the magnet in which its magnetic force will work. Though magnetic fields and lines of force are invisible, they can be felt. They can be seen as well when we utilize iron filings. Pictures of these patterns can be saved for display and study.

Challenge:

Experiment with iron filings and magnets to find magnetic fields and lines of force. Compare and contrast examples from various magnets.

Materials and Equipment:

Cardboard or paper plates
Bar magnets
Circular magnets

Iron filings
Horseshoe magnets

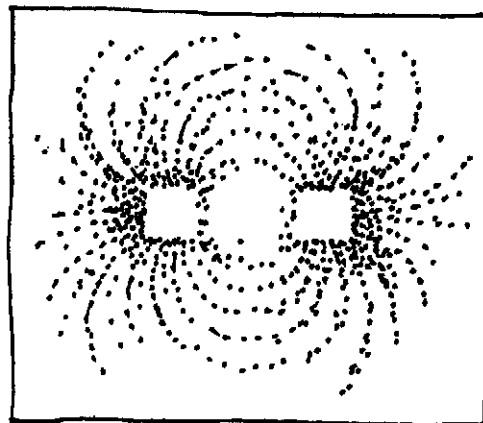
Procedure:

Have the children place cardboard or paper plates over various shaped magnets as shown on the drawing above. Sprinkle the iron filings over the cardboard and tap gently so that the filings are evenly distributed along the lines of force of each magnet. The magnetic field will also be shown. Preserve the patterns by spraying them with clear acrylic.

Further Challenges:

- ☐ Repeat the experiment to see if the patterns remain the same.
- ☐ Try the experiments with weak magnets versus strong ones.

tap edge of
card - iron
filings
align with
magnetic
lines of
force



Top view

Generating Homemade Electricity

by Mark R. Malone

Focus:

An electrical generator is a device that converts mechanical energy into electrical energy by moving a wire through the magnetic lines of force of a magnet. The amount of electrical current produced can be affected by using more or stronger magnets, by using more coils of wire, or by increasing the spinning speed of the generator.

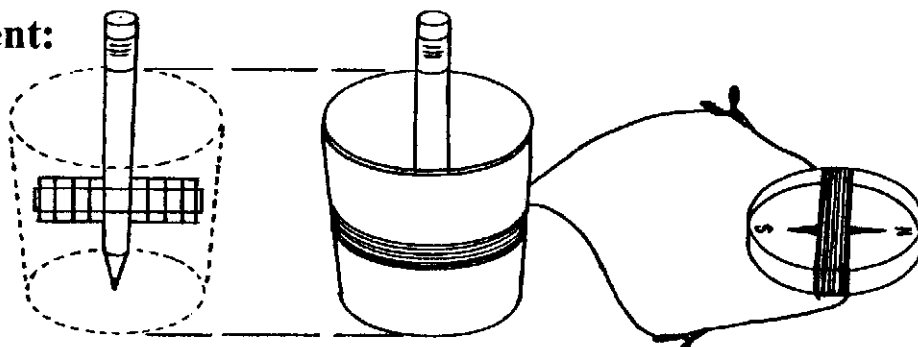
Challenge:

What factors affect how much electricity is generated by a simple generator.

Once the students have seen that current can be generated in this manner, a systematic investigation may be carried out. Students should be instructed to explore the factors that affect how much current is generated. The most obvious factor is how rapidly the bar magnet is spun. The strength of magnets could also be tested. Another variable that can be explored is the number of turns of wire around the cup. The number of turns of wire can be increased and the amount of current produced can be inferred from the compass. Students could wrap 10, 20, 40, 80, 160, and 320 turns of wire around the cup and compare results.

Materials & Equipment:

Strong rectangular magnets
Enamel coated bell wire
Alligator clips
Paper or foam cup (apx. 6 oz.)
Sharpened pencils
Magnetic compasses



Procedure:

To construct the system, wrap the magnetic compass with a length of enamel wire as shown at the bottom of page. Bare the ends of this wire. Coil the enameled wire around a paper cup as shown in the drawing. It may be helpful to place tape over the coils of wire to hold them in place. There is no set number of turns though increasing the number of turns of wire will increase the effect. Attach alligator clips to the bare ends of the wire. Connect the alligator clips to the bare ends of the compass coil wire. Tape ten small magnets to a pencil as shown in the drawing. Position them on the pencil such that they will be at the same height as the coil of wire when spun in the cup. The pencil holding the magnets can be spun more easily if a small hole is poked in the bottom center of the cup. This helps to hold it in place and to spin more freely.

Spin the magnets inside the cup. The current generated is indicated by movement of the compass needle. Because the electricity generated is alternating current, the needle moves back and forth in rhythm with the spinning of the magnets. The degree to which the needle moves back and forth indicates much electrical current is being produced.

Unfortunately, the nature of the homemade meter does not lend itself very well to data which are readily recorded and analyzed. Because the system produces alternating current rather than direct current, the change in direction makes readings of strength difficult to measure. Students will have to judge, based on the movement of the compass needle, which system seems to produce the strongest effect.

Further Challenges:

- ☐ Can students design a system that would produce enough electricity to light a flashlight bulb?
- ☐ Ask students to describe in their own words how a generator works.
- ☐ Ask students to find out how alternating and direct current differ.
- ☐ Use a commercial volt or amp meter to measure the strength of the electricity produced with variations of magnet strength, spin speed, and number of wire winds.

Powering the Motor/Generator System

by Mark R. Malone

Focus:

Most commercial generators are simply variations of materials used in the previous activity (*Generating Homemade Electricity*). The main difference between commercial generators and the one constructed for that activity is that the commercial generators use a spinning coil of wire inside a magnetic field rather than spinning magnets inside a coil. Most commercial motors and generators are constructed in this manner. A motor and a generator are nearly identical in terms of their internal components. Therefore, any motor that contains permanent magnets can also serve as a generator simply by spinning

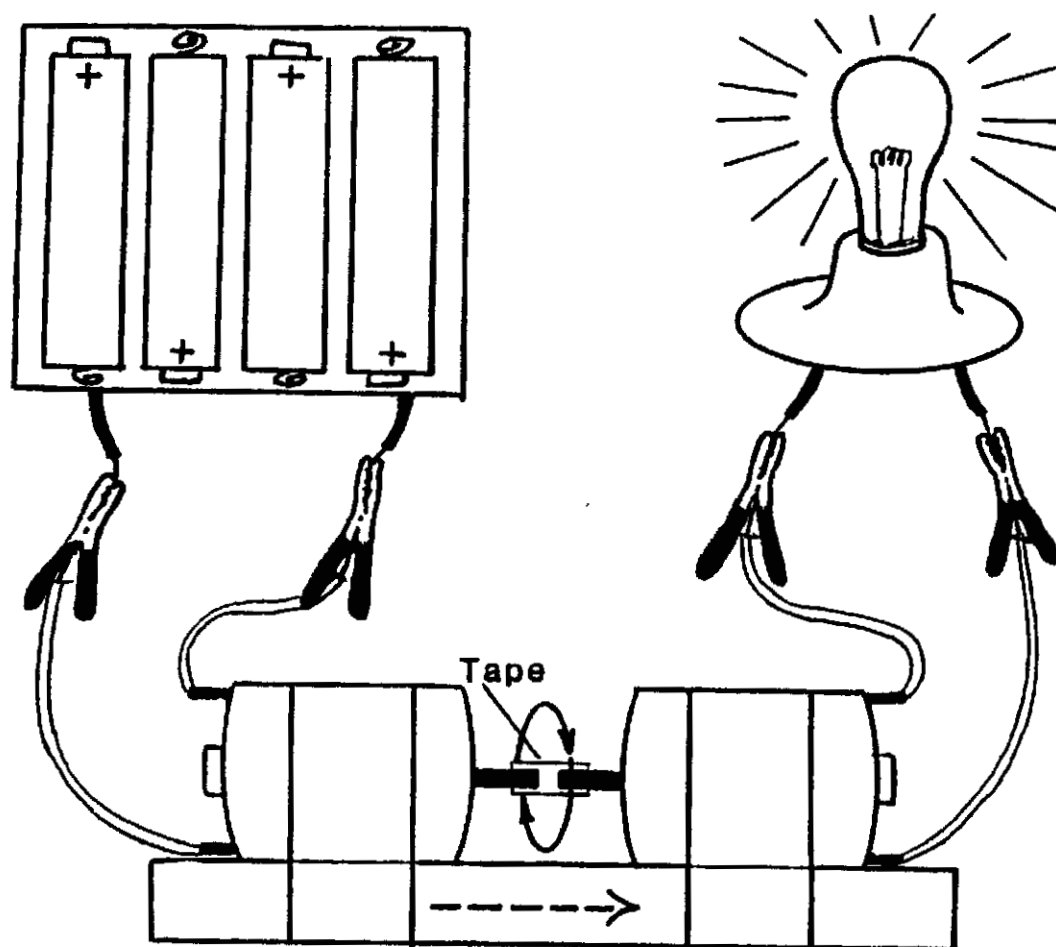
its shaft. The faster the shaft is spun, the greater the amount of electrical current generated.

Challenge:

Ask students to determine various factors that might cause the simple generator to produce more electrical current.

Ask students why it is possible for a motor to be used as a generator.

Determine what happens when more dry cells are added to the motor/generator system.



Motor powered by battery → Generator powered by motor

Materials and Equipment:

Electric motors (1.5 - 3 volts DC)
Light bulbs (1.5 - 3 volt)
Light bulb holders
Plastic coated bell wire
Alligator clips
Dry cells (AA)
Dry cell holders
Small wooden base (apx. 1 x 4 inches)
Clear carton tape

Procedure:

When constructing the motor/generator system, two motors must be joined shaft to shaft. The two shafts can be easily joined by wrapping them with a piece of carton tape which has been cut to size. The motors could be fastened to a mounting board by a number of means, but using clear carton tape makes all of the parts of the system easily visible while being used. Connections of alligator clips to wires should be soldered as shown.

Assemble the motor/generator system as shown on the previous page. Fasten the electrical leads from one motor to the bulb holder. Fasten the leads from the other motor to the battery holder. Note that although there is no direct electrical connection between the battery pack and the second motor, the light bulb attached to the second motor lights. This is caused because the second motor is serving as a generator. When the number of dry cells is increased (2, 3, or 4 cells) the motor/generator system speeds up and the light bulb burns brighter. Students should discuss why this is possible.

Small electric motors such as those found in most battery powered toys consist of several easily recognizable parts: two small magnets glued to the inside of its case, a shaft that holds small coils of wire, coils of wire that are often wrapped around iron cores that increase the power of the motor, and brushes that conduct electricity to the coils of wire. If the shaft of the motor is spun rapidly, such as when connected to another motor, the system converts the spinning energy into electrical energy that can be seen when the light bulb glows.

Further Challenges:

☐ As a follow-up to this activity, have students disassemble the third motor to determine its internal components. Most small motors can be easily disassembled with a pocket knife

by bending back small clips that hold it together. Those that are built a little better may require prying with a small screwdriver and pliers. Students should identify and label the internal parts and try to determine how they function as a generator and/or motor.

☐ Will a bulb powered by the motor/generator system stay lit as long as one powered directly by the battery? Why or why not? Can you determine the efficiency of the motor generator system? This can be done by timing how long a bulb lights when fastened to the motor generator system (*Time 1*) and timing how long a bulb lights when fastened directly to the battery (*Time 2*). Using this method, the system is generally determined to be approximately 60 percent efficient.

$$\text{Percent Efficiency} = \frac{\text{Time 1} \times 100}{\text{Time 2}}$$

I Didn't Know the Generator Was Loaded

by Mark R. Malone

Focus:

All electrical systems have a maximum amount of force that they can exert in a given period of time. If the amount of work required by an electrical system is increased, one of three things will likely happen: 1) the work will be done slower and require more total energy, 2) the work will be only partially done if no additional energy is available, 3) the system may be so overloaded that no work is done. If a system is overloaded to a point where it is undesirably slow or no work can be done, addition of more force by adding a new power subsystem may enable the system to continue to function or to function faster.

Challenge:

Predict the likely effects of increasing the load on a system.

Materials and Equipment:

Electric motors (1.5-3 volts DC)

Wooden base (apx. 1 x 4")

Light bulbs (1.5-3 volt)

Light bulb holders

Plastic coated bell wire

Alligator clips

Dry cells (AA)

Dry cell holders

Clear carton tape

Aluminum foil

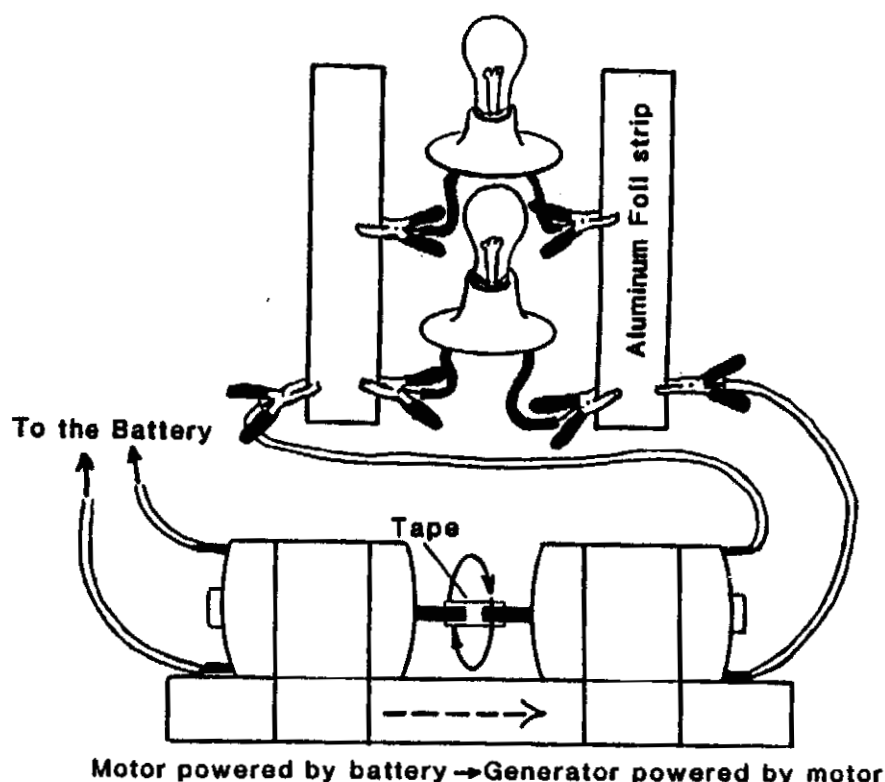
Procedure:

Assemble a motor/generator system as described in the previous lesson (*Powering the Motor/Generator System*). Have students start the system running. One by one, connect light bulbs to the generator end of the system as shown below. Bulbs should be added to the system in parallel circuits. Students should observe changes in both the speed of the motor/generator system and the brightness of the light bulbs as more bulbs are added. Students

may also explore the effects of adding bulbs to the system in series versus parallel. A series arrangement draws less power, but fewer bulbs can be lit.

Further Challenges:

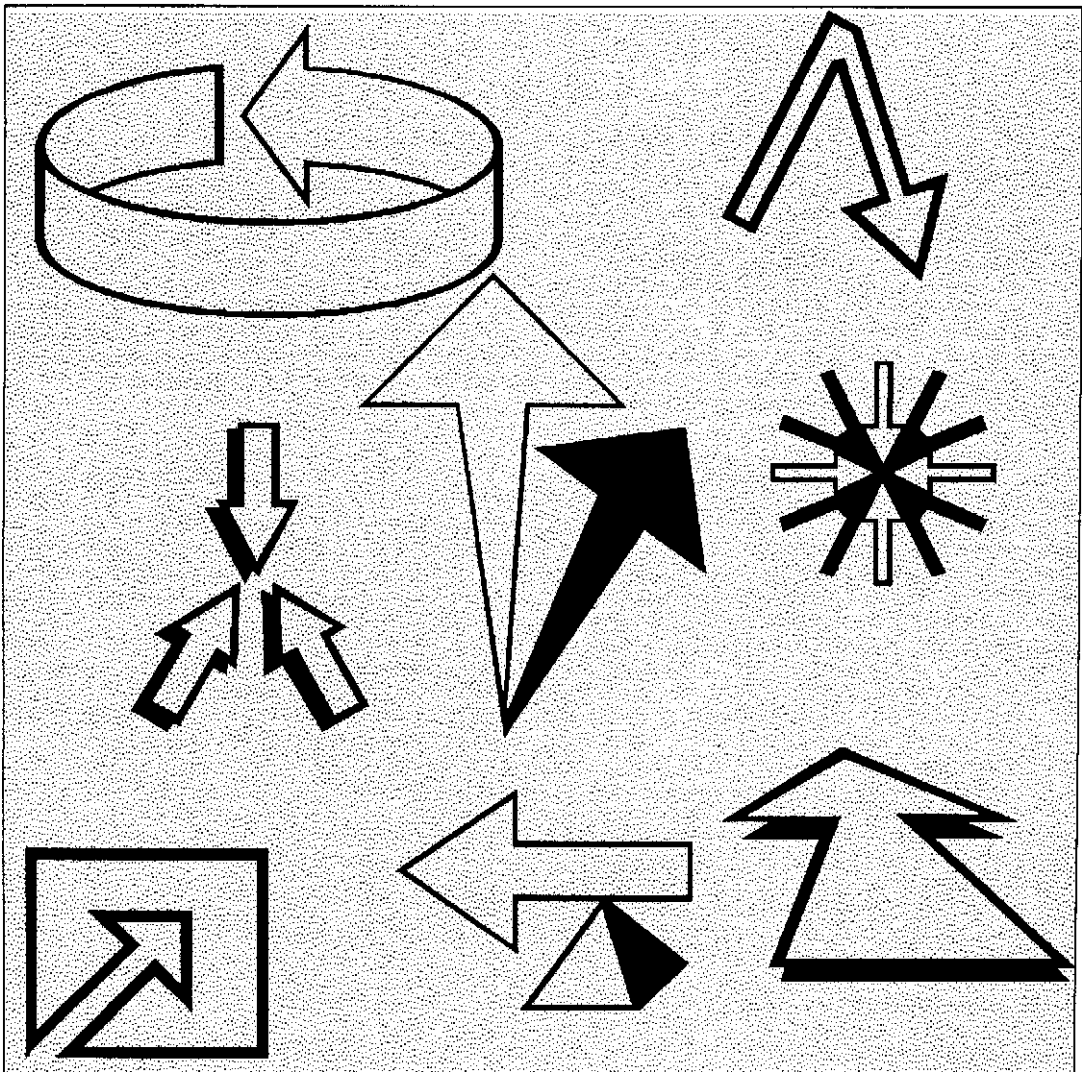
□ Describe how the concepts of load with the motor/generator system are related to load on a municipal electrical generating station. (*A municipal power generating station must be prepared for the largest expected load of a community or area. When the base load generators are working at near full capacity and more power demands are expected, more expensive generators that often sit idle must be put into service. If a community as a whole could cut the amount of power required through conservation, the overall cost of power to the area would be reduced because no new power generators would have to be built and existing reserve generators could be used less often.*)



Motor powered by battery → Generator powered by motor

CHAPTER 6

FORCES AND MOTION



Don't Tag Along

by Patsy Ann Giese

Focus:

Any stationary object tends to stay stationary unless acted on by an unbalanced force. Any moving object tends to stay moving, following a straight line path at constant speed unless acted on by an unbalanced force. This property of matter is called inertia. An unbalanced force changes an object's motion towards the direction of the force.

Challenge:

Observe the effects of inertia.

Materials and Equipment:

Index cards Paper punch
String Glasses or cups
Washers or coins

Procedure:

Have each student place a card with a string tied to it over an empty glass or cup. They should place a coin or washer on the card and jerk the string. If the jerk is hard enough, the washer or coin will fall into the container. *(A steady gentle pull will not overcome friction between the washer or coin and the card.)*

Have each student stack several wooden blocks on top of a block with an eyelet and string. Jerk the string. If the jerk is hard enough, the lowest block will slide forward without the upper blocks.

Further Challenges:

☐ Put a ball in the back of a wagon. Pull the wagon for awhile, and then stop suddenly. Have students observe the motion of the ball rolling forward after the wagon has stopped. Explain that the motion is due to the ball's inertia.

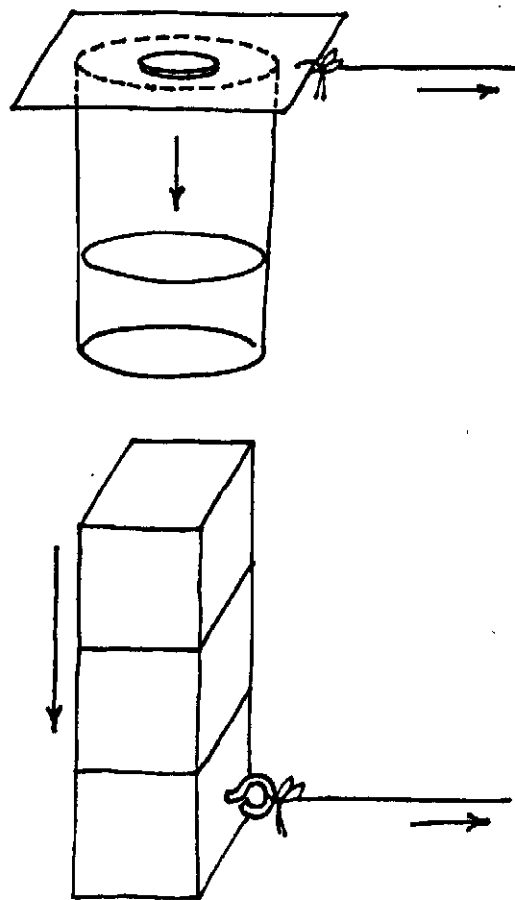
☐ Have each student place a coin in a cup held with the open end vertical. They should walk fast for a few seconds with the open end of the cup forward, and then stop suddenly. The coin will continue to move forward.

☐ Have a student grasp a ball using only their fingertips and hold the ball with their arms and hand extended downward. Have another student standing about 25 meters away grasp another ball similarly. Have the first student run past the second. At the moment they are together, a third student should yell, "drop." Compare the paths of the two dropped balls.

☐ Discuss why a person falls forward in a car or an airplane that stops suddenly. Discuss why a one feels pushed back into a seat in a car or airplane that starts suddenly.

☐ Ask students to imagine they are standing in front of someone on a bus. Ask if it is likely that the other person will fall against them if the bus starts suddenly or stops suddenly.

☐ Discuss why a person can coast on a bike even if they are not going downhill.



Inertia

by Nadine Halligan

Focus:

Most states now have laws requiring the driver and passengers in a car to wear seat belts. Investigate Newton's First Law of Motion (*the Law of Inertia*) and why this physical law has caused the enactment of seat belt laws. (*Inertia is the tendency for an object at rest to main at rest or to remain in motion unless affected by an outside force.*)

Challenge:

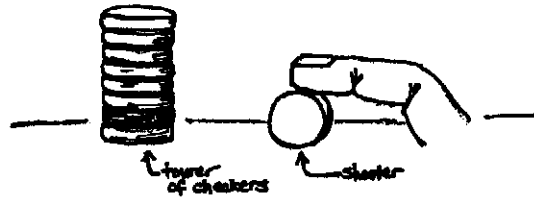
Perform a series of activities and observe carefully. What do the activities have in common? Look especially at where force is being applied and what is moving in response to that force.

Materials and Equipment:

Backgammon or checker pieces	Pennies
Coffee cups (<i>sturdy</i>)	Index cards
Small toy cars	Modeling clay (<i>plasticine</i>)
Plastic eggs (<i>e.g. L'eggs</i>)	Saucers (<i>sturdy</i>)
Nylon cloth (<i>apx. 1 meter</i>)	Water
Wood blocks (<i>apx. 5 x 5 x 25 cm</i>)	Liter soda bottles
Sand	Paper (<i>legal size</i>)

Procedure:

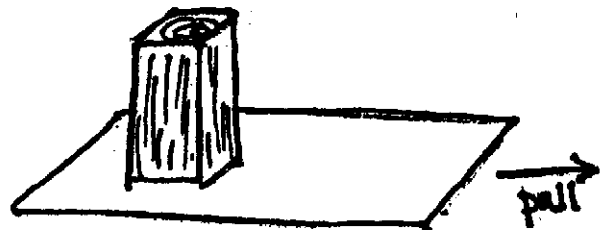
Snap the checkers: Set up eight checkers in a straight stack. All checkers should be the same color except the one second from the bottom. A single checker is placed on end. It is shot toward the stack by placing an index finger on top of it and pressing down so that the checker rolls forward as the finger moves backward. When aimed correctly, the second to the bottom checker in the tower shoots out from under the stack and the rest of the checkers remain standing in a stack. It may be helpful to erect barricades around the checkers so that they do not go flying all over the room if someone should miss.



Penny drop: Place a penny on top of an index card on top of a coffee cup. By tapping the edge of the card only, the penny drops directly into the cup as the card flies out from under it. What would you expect would happen if this were done while in outer space? (*Hint: there is no gravity.*)



Snatch the paper: Place a piece of legal size paper on a desk, then place the wood block on end on it toward the edge of the paper. The end of the block should be sanded smoothly. Remove the paper without lifting the block or knocking it over. If the edge of the paper farthest from the block is pulled smartly, the block should remain standing.



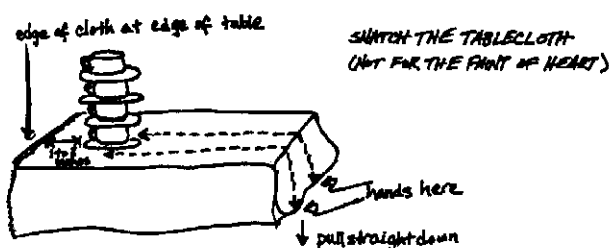
Spinning eggs: This activity can be done with real eggs, but that may cause a major mess. Place 50 grams of plasticine clay inside one L'eggs egg and 50 ml of water inside another. The eggs should have the same mass. Be sure that the egg containing the water does not leak. Place

each egg on a saucer and have a pair of students spin them at exactly the same time. Which stops first? A liquid has more inertial drag than a solid, so the liquid filled egg will stop first. How can this be used to tell hard boiled from raw eggs?

Man in the car: This activity is directly related to seat belts. Form a standing clay figure big enough to fit in a small toy car and start the car rolling with a push. Stop the car suddenly by sticking a finger in front of it or crashing it into a wall. What happens to the man?

Further Challenges:

☐ Ask students to explain how a table cloth can be snatched from beneath a set of cups and saucers containing water without spilling a drop. Do this demonstration by purchasing heavy, glazed cups and saucers from a restaurant supply house. Be sure that the bottom of the saucer is completely glazed. Place the unhemmed nylon cloth on a clean and smooth desk so that one edge is even with the desk edge. Show the students the cups and saucers as you alternately stack a cup on a saucer to prove there is nothing strange about the cups. With each cup, be sure to fill it half full with water. Do not spill any water on the cloth as you build the tower. Ask the students to predict whether the cups or saucers will fall and why. To successfully snatch the tablecloth, hold the end of the tablecloth which is opposite the cups and place your hands so that they are just on either side of the cups and saucers. When you feel confident, pull the cloth *straight down* toward the floor *very quickly* to counteract any friction which can knock the cups over. In this case friction is the outside unbalanced force that can cause the saucers to fall.



☐ Discuss which brakes you should put on first when coming to a stop on bike with hand brakes.

☐ Discuss past experiences where students may have noticed inertia.

References:

Brown Robert J. (1984) *333 Science Tricks & Experiments*. Blue Ridge Summit, PA: Tab Books, Inc.

Gardner, Martin. (1981) *Entertaining Science Experiments with Everyday Objects*. New York, NY: Dover Publications, Inc.

Mandell, Muriel. (1968) *Physics Experiments for Children*. New York, NY: Dover Publications Inc..

Ontario Science Center. (1986) *Scienceworks*. Reading, MA: Addison-Wesley Publishing Inc.

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Vivian, Charles. (1967) *Science Experiments and Amusements for Children*. New York, NY: Dover Publications, Inc.

Finding the Velocity

by Michael J. Demchik

Focus:

Uniform velocity of an object is defined as one which has the same displacement during each second of motion. $\text{Distance/time} = \text{velocity}$ is the simple equation by which this uniform velocity is defined.

Challenge:

Predict the velocity of the rolling ball by observing its motion along a rail.

Materials and Equipment:

Half round molding strips (two 3 meter strips and two 50 cm strips)

Several small scrap pieces of wood

Small nails (brads)

Small rubber ball

Stop watch

Procedure:

Prepare a three meter track by putting together two three meter sections of half round molding strips with small cross pieces nailed underneath. Prepare another 50 cm rail to act as a ramp for a ball. (See the drawing below.) The width of the rail and ramp depends on the size of the ball. One width that could accommodate several sized balls would be appropriate. The ramp may be supported by books in order to get the desired velocity.

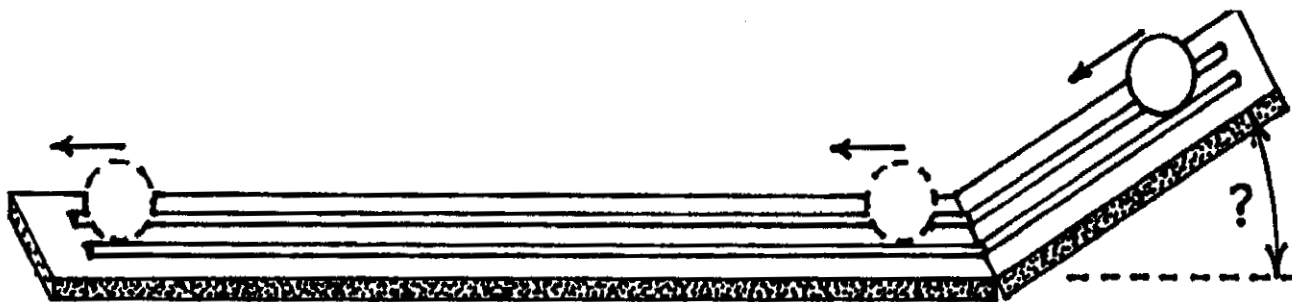
Allow the ball to roll down the ramp and start the timer as it strikes the rail, then stop the timer when the ball reaches the end of the rail. The velocity can be determined by dividing the distance (*three meters*) by the time in seconds. The ramp may be raised a number of times to get the velocity arrived at different ramp heights above the ground. The ramp height versus the velocity can be plotted on a graph.

Further Challenge:

☐ Convert each value arrived at for the velocity at various heights to values in kilometers per hour (kph). The following formula gives a good estimate of kph:

$$\frac{3.6}{\text{seconds}} \times \text{distance in meters} = \text{kph}$$

☐ What is the optimum angle to get the fastest speed? Slowest speed?



Meter Beater

by Sue Dale Tunnicliffe

Focus:

This work focuses on the relationship between the speed of a vehicle, the distance it travels, and the time it takes. Through doing this activity students usually come to understand the formula in their math work:

$$S \text{ (speed)} = \frac{d \text{ (distance)}}{t \text{ (time)}}$$

Challenge:

What is the fastest you can get a given toy car to travel? How are you going to produce the speed of the test car? How can you increase this speed? How will you measure speed? Is there a relationship between speed, distance and time?

Materials and Equipment:

Toy car (*should roll freely*)
Stop watch
Ramp support (*books*)
Chalk

Ruler
Smooth rolling surface
Ramp (*board*)
Recording sheet

Procedure:

Students need to have had previous experience of running toy cars down slopes of various heights to see that the higher the slope, the further the car will run. They also need to be able to use a stopwatch and use a ruler for measuring distance. You may wish to assign various roles to students, e.g., a time keeper, a distance measurer, a data keeper, a starter, a retriever.

Encourage the groups to discuss what they already know that is relevant to the challenge. What do they think will happen in light of their previous knowledge and experience? How will they record their results?

Provide students with a data recording sheet (*as shown below*).

Further Challenges:

- ☐ What is the effect of altering the height from which the run starts?
- ☐ What effect is produced by altering the surface on which the car runs?
- ☐ What happens if you change the car being tested?

Test Run Number	Distance Traveled	Time	Speed
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____
6	_____	_____	_____

Out of Gas

by Sue Dale Tunnicliffe

Focus:

This investigation focuses on the rate of movement of a toy car.

Challenge:

Does the weight of a moving object such as a toy car have any effect on the distance it will travel before stopping? What do you already need to know? How can you ensure that it is a fair test? Should you use the same car for all the tests?

Materials and Equipment:

Toy cars	Modeling clay
Balance	Meter stick
Floor	Ramp and support

Procedure:

This activity works best in small groups of three to four students. Get the groups to organize their roles such as

director of operations, data collector, chief measurer, director of communications.

Each group needs to discuss the task, brainstorm some solutions, and then choose one for experimentation. They should design their experiments and predict the outcome before collecting equipment and assembling it.

Encourage the students to draw up a table to fill in their experimental results. Each test should be repeated at least three times to obtain an average reading.

A line graph showing the distance traveled against weight of vehicle should be drawn.

Evaluation of the experimental method should occur and the results and evaluation presented to the class.

Further Challenges:

☐ If the same car and load traveled over different surfaces, what would you expect to happen?



Marble Momentum

by Mark R. Malone

Focus:

Several concepts related to energy transfer can be demonstrated with this simple apparatus. Students can design and conduct investigations that show various aspects of energy transfer: (1) As the mass of an object is increased, more energy is required to move it. This activity demonstrates the effects of an increase in inertia as the number of washers on the slider is increased. (2) They can also determine that if the energy in a system is increased and a mass to be moved remains the same, the mass will move farther. In this demonstration, increasing the number of marbles increases the total energy available for transfer to the slider. This demonstrates a key attribute of momentum. (3) They can also study the optimum efficiency of a system when the angle of a ramp is changed. As the angle of the ruler is increased, the marble's position becomes higher. While more total energy is available, at very steep angles much of the energy is lost due to impact with the rolling surface. (4) Effects of friction on the system can be studied by placing the slider on various

surfaces. In addition, students gain practice in conducting a controlled investigation, gathering data, and interpreting those data.

Challenge:

In the ramp and slider picture shown below, how will the distance the slider slides be affected by the number of washers added to the slider?

Materials and Equipment:

Plastic ruler (12 inch or 30.5 cm) grooved down the center

Paper cup (approx. 250 ml)

Metric ruler

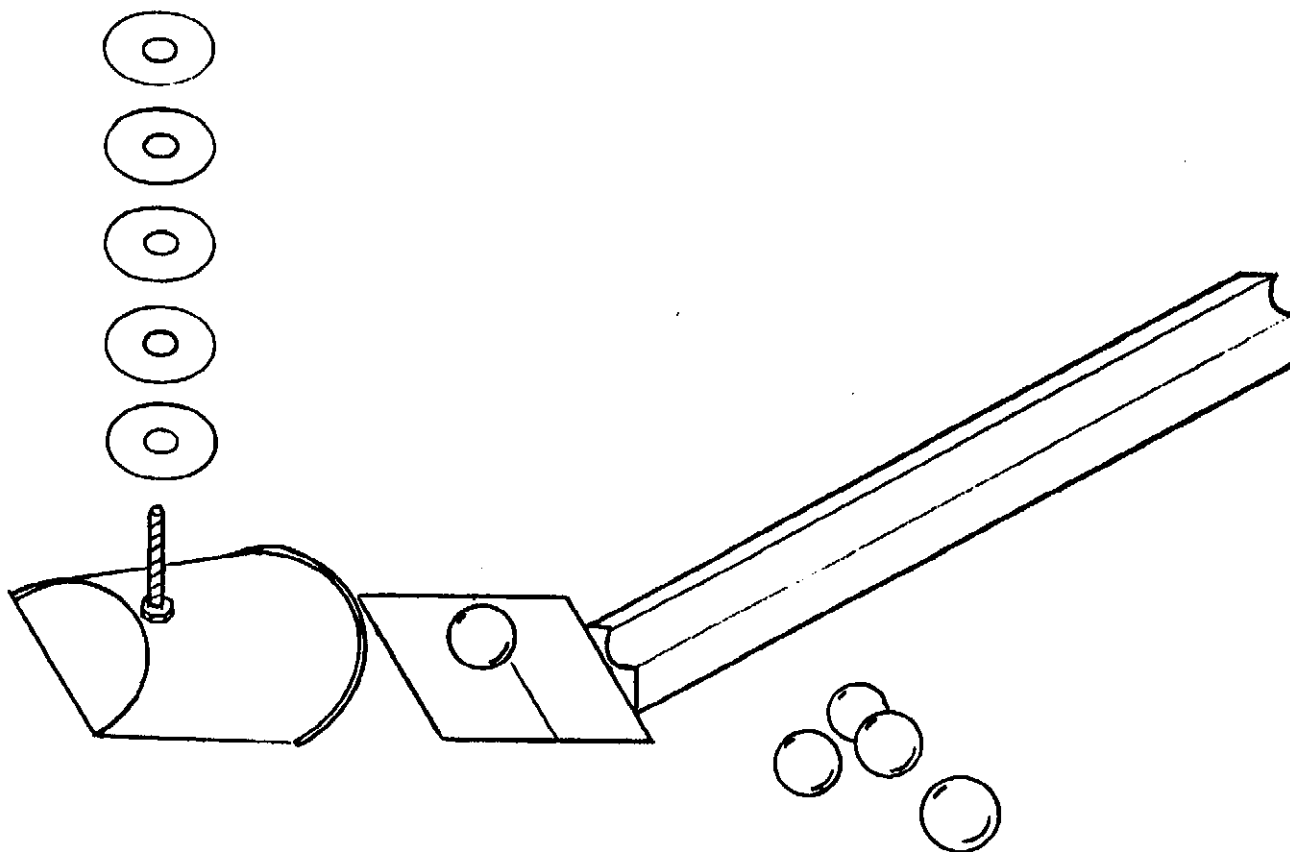
Small glass marbles

Large glass marble

Machine screw with nut (approx. 35 mm long)

Flat washers (approx. 25 mm in diameter)

Masking tape



To construct the slider, as shown, cut a paper cup in half vertically. Punch a small hole approximately 2 cm from the bottom of the cup and midway between the edges. From the inside of the cup, insert a screw through the hole and attach it with a nut on the outside. The screw will hold the washers that will be used to increase the mass of the slider.

Procedure:

Students may begin this activity by rolling marbles down the ramp (*ruler*) and measuring how far the slider (*cup*) moves. You may wish to let them freely explore how various arrangements of the materials affect the distance the slider moves.

After a period of free exploration, students can proceed to systematically add one, two, three, four, or more washers at a time to the slider and compare how these additions affect the movement of the slider. Measurements of the slider's movement should be taken and recorded. You may also wish to have students graph the data for various trials. Students should see clearly that as the number of washers on the slider increases, the distance the slider moves decreases. You may wish to formally label this activity in terms of inertia and energy.

Further Challenges:

☐ Ask students to give examples of inertia from their personal experience.

☐ Challenge students to determine the effect of increasing the number or size of marbles released from the ruler. This demonstrates a key momentum concept that as the mass of a moving body is increased, it can impart more energy to a stationary body. Ask students to give examples of momentum from their personal experience.

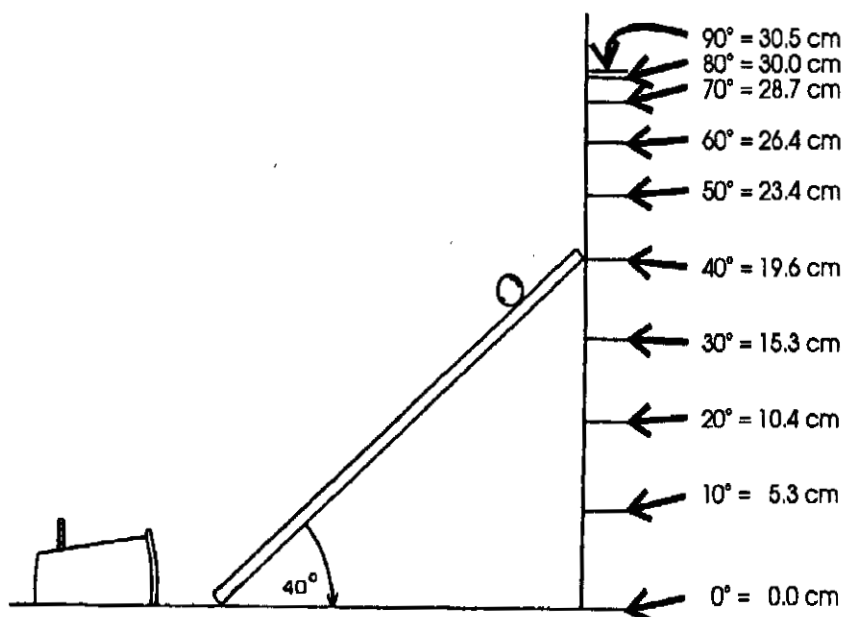
☐ Challenge students to explore the effects of changing the angle of the ruler on the movement of the slider. (A means of setting various angles is shown in the drawing below.) Ask students to determine the optimum angle to impart the most

energy into the slider. Can students explain why initially increasing the angle increases the energy imparted, while further increases in angle decreases the energy imparted? Can students give other examples of optimum operating range from their personal experience?

☐ Challenge students to determine the effects of placing the slider on various surfaces (sandpaper, waxpaper, newspaper, wood, concrete, linoleum, etc.). Ask them to give other examples of friction from their personal experience.

Reference:

Malone, M. R. (1986) "Investigating Ramps and Sliders," *Science and Children*. February, pp. 11-14, 1986.



Ramp at Various Heights

Soup Can Races

by Gerald W. Foster

Focus:

To observe the influence of different densities of liquids upon rolling motion.

Challenge:

Students will attempt to figure out why some soup cans roll farther and faster than others.

Materials and Equipment:

Plywood sheet (approx. 250 cm x 60 cm x 2 cm - 8' x 24" x 3/4")

Books

Meter stick

Hollow and solid cylinders (approx. 6 cm x 1.5 cm)

Plastic bottles (apx. 500 ml)

Liquids (such as oil, water, soap, alcohol, etc.)

Soup cans (should have the same weight and diameter)

Meter stick

Stop watches

Metric measuring cups

bottom of the inclined plane and measure the distance they roll before stopping. When using the cylinders, students can compare hollow versus solid of the same material. They may also compare materials identical in size but made of different materials. Objects made of the same material but of different sizes can also be tried.

Finally, students can organize their data in charts for each of the three sets of materials.

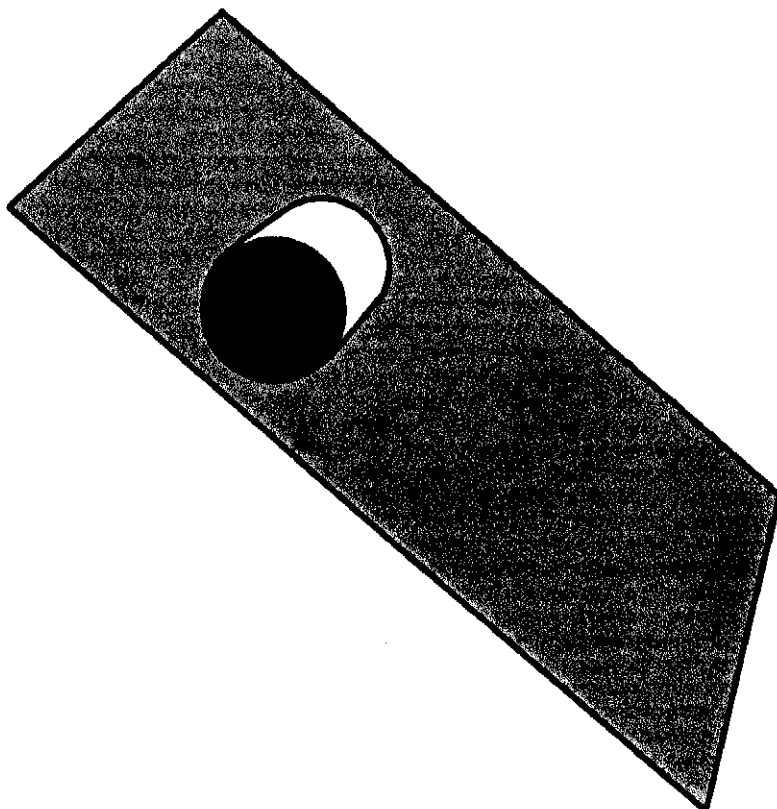
Further Challenges:

- ☐ Change the height of the inclined plane.
- ☐ Try other types of canned food such as spaghetti and tuna.
- ☐ Try other types of canned food and liquids but in different sizes.

Procedure:

Prior to rolling the soup cans, students may need help visualizing what is happening in the soup cans. This can be accomplished by using the cylinders to see the behavior of rolling solid and hollow objects. The liquids in the soup cans behave like hollow and solid rolling objects. The clear plastic containers of liquids allow students to see what is happening inside a soup can.

Students may start with the cylinders, then the clear plastic bottles, and, finally, the soup cans. The soup cans should contain materials that range from almost solid to completely liquid. In each case students can time how long it takes the objects to reach the



The Amount of Matter Doesn't Matter

by Patsy Ann Giese

Focus:

If air caused no friction, light and heavy objects dropped from the same height would take the same amount of time to hit the ground.

Background:

With little or no friction, all objects accelerate (gain speed) as they fall. The amount of this acceleration, called "g," is the same for all objects.

Air friction noticeably slows falling objects that are not streamlined. Air friction increases as an object gains speed. When friction gets large enough to balance an object's weight, the object stops accelerating and starts falling at a constant speed.

Challenge:

Predict which objects will fall faster than others.

Materials and Equipment:

Ball	Feather
Paper	Metal dowel
Wooden dowel	

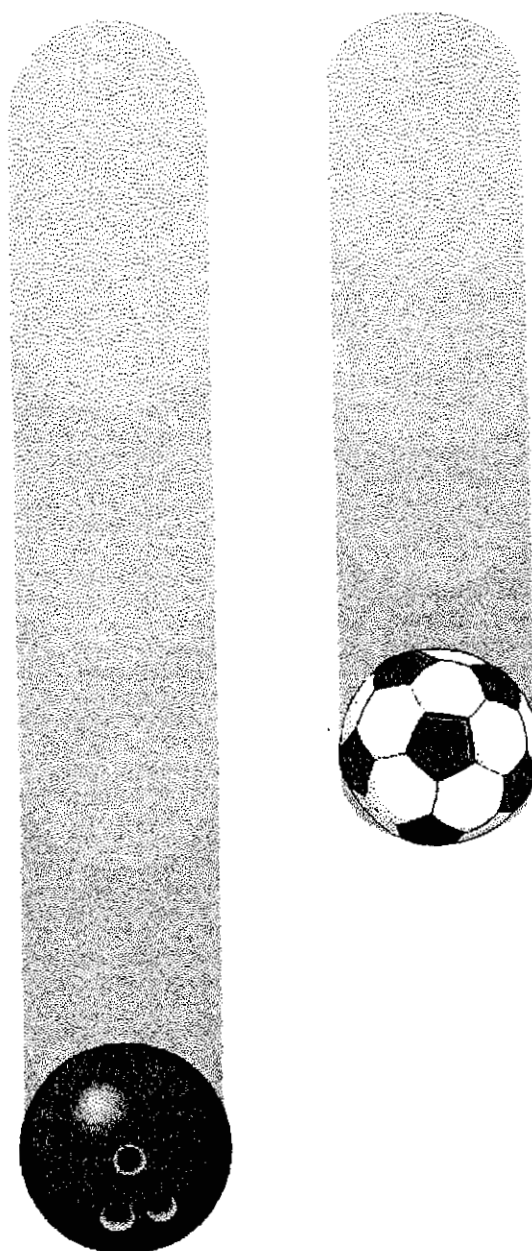
Procedure:

From the same height and at the same time, drop a ball and a feather. Have students form hypotheses as to why the ball hit the floor before the feather. Ask students to design experiments to test their hypotheses about the ball and feather. Remind students not to throw objects downward because that would not be a fair test of which variables affect free fall.

Students could drop a metal and a wooden dowel of the same size and shape to test if mass affects the time of fall. Students could drop a crumpled and a flat piece of the same type of paper to test if shape affects the time of fall. Other objects can be substituted for these if pairs of objects. Try to find objects in which only one property is different. If variables are not controlled, as in the ball and feather test, hypotheses cannot be tested.

Further Challenges:

- ☐ Discuss what would happen if the ball and the feather were dropped on the moon.
- ☐ Discuss why a parachute slows a person's fall.
- ☐ Discuss why a heavy person will fall faster than a light person when both have identical parachutes.



STICKING POWER

by Michael J. Demchik

Focus:

The adhesive force between various materials varies depending on the type of material and its composition. The force of attraction can be measured and compared for various materials.

Challenge:

What are the criteria for good adhesive power? How can adhesive power be measured?

Materials and Equipment:

Various flat surfaces (i.e., glass*, wood vinyl)
Various types of tape (i.e., masking, cellophane, adhesive)
Books (or other materials to support flat surfaces)
Many heavy masses (i.e., large steel washers)
Large paperclip

Procedure:

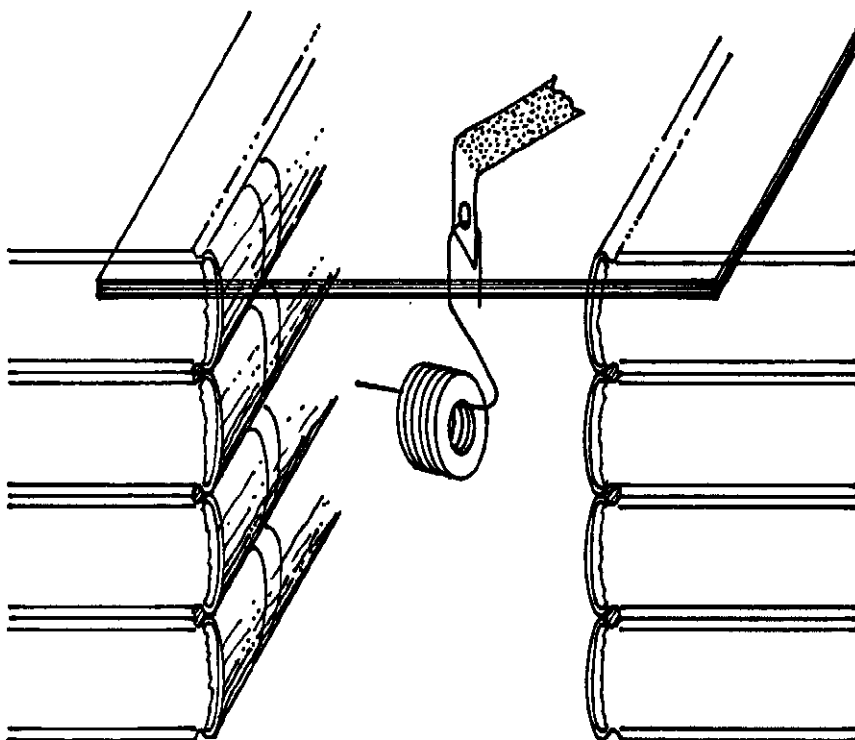
Cut one piece of masking tape approximately 4 cm in length. Cut a small piece of paper to cover 2 cm of the length of the tape. Use a hole punch to make a small hole near the end of the piece of tape covered with paper. Stick the other end of the tape to a flat surface such as a sheet of glass. Suspend the piece of glass, tape side down, over a support such as stacks of books as shown below. Bend a paperclip to form a hook on each end. Place one end of the paperclip through the hole punched in the tape. One by one, add washers or similar masses to the paperclip hook until the tape falls free of the glass. Follow the same procedure with various lengths of tape. Graph the length of tape versus the amount of mass required to remove it. Draw conclusions about the relationship of length of tape to the amount of mass required to pull it free of the glass.

Further Challenges:

- ☐ Have students repeat the investigation using various types or brands of tape.
- ☐ Have students explore how well tape adheres to various surfaces by replacing the glass with other materials.

Safety Tip:

*Glass works well for this investigation, however, it presents potential safety hazards. Caution students to be careful when handling glass. Have safety procedures for cleanup for broken glass. It may be advisable to cover the edges of the glass with tape.



Center Of Gravity

by Michael J. Demchik

Focus:

The center of gravity is the point in a body around which its weight is evenly balanced. The center of gravity will determine the point or points where an object will balance.

Challenge:

Where is the center of gravity of an object? What factors, if any, affect the center of gravity?

Materials and Equipment:

Pencils	String
Supports	Tape
Washers	Stiff wire

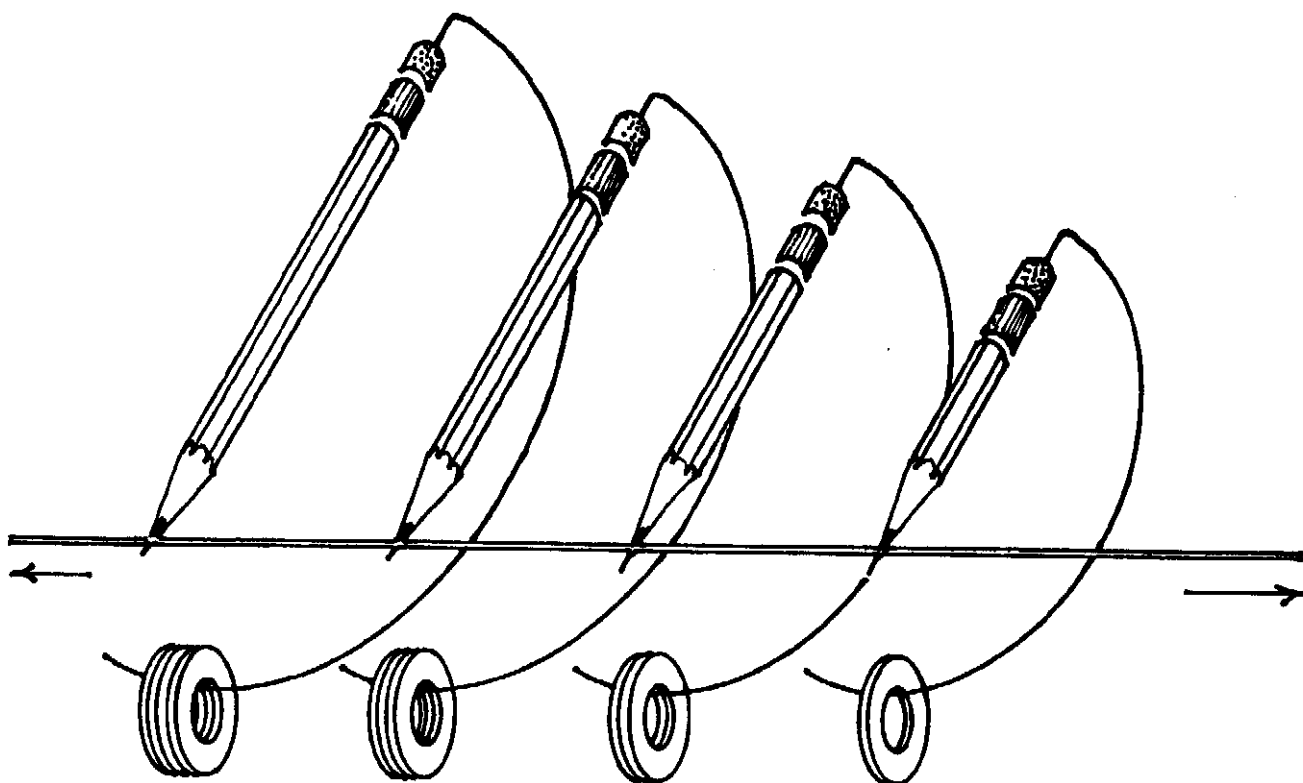
Procedure:

Start by sharpening several pencils to various lengths. Cut a piece of wire somewhat longer than each pencil. Bend the ends of each wire and shape the remainder into a curve as shown. Insert one end into the eraser portion of the

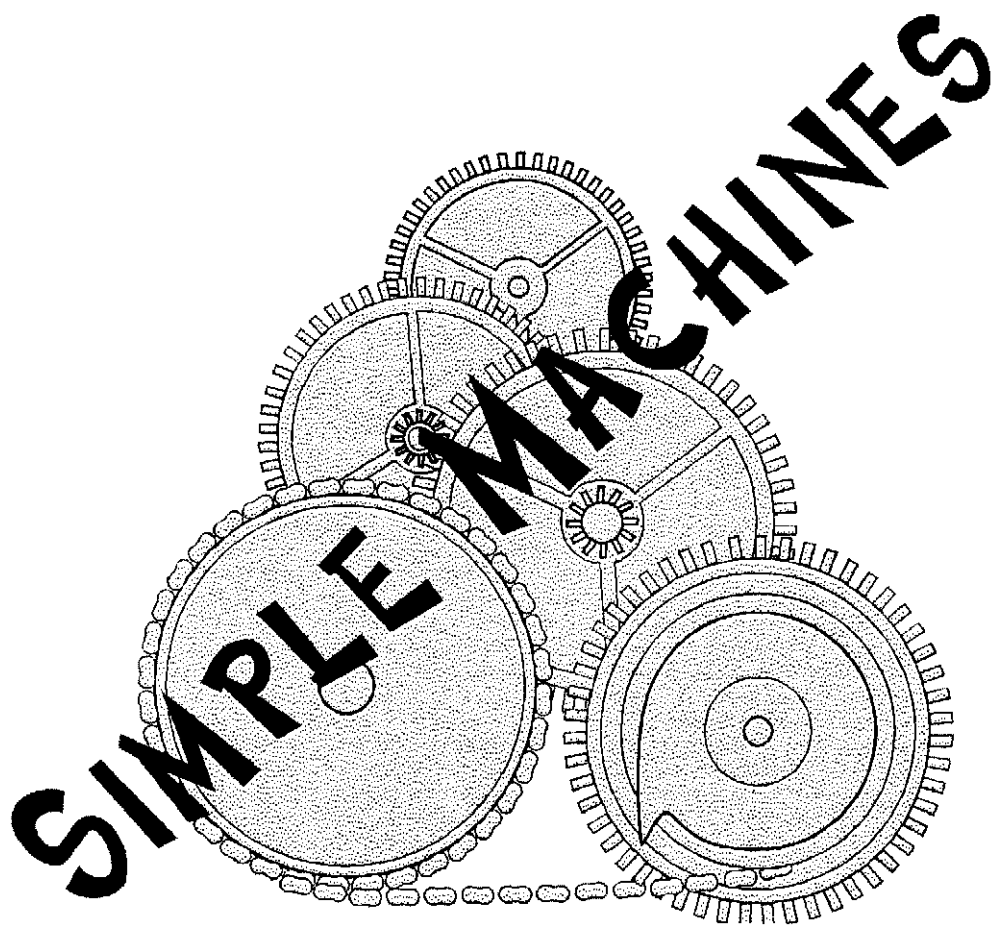
pencil. Tie a string between the two supports. Place the tip of one of the pencils on the string and balance the washers on the free end. Do the same with the remaining pencils. Line them up from largest to smallest. Have the students account for all the variables that are involved in this arrangement.

Further Challenges:

- ☐ Have students locate readings about "Center of Gravity."
- ☐ Have students experiment with methods of determining the center of gravity for various objects.
- ☐ Have students experiment with balancing pencils of the same length with differing numbers of washers



CHAPTER 7



I'm Inclined

by Sue Dale Tunnicliffe

Focus:

This activity is concerned with making work easier by using a ramp or incline as a simple machine.

Challenge:

Can you move a mass through a given vertical height by means other than a straight vertical lift? The method employed must use less effort than the effort needed for a straight vertical lift. Effort is measured on a spring balance. How could you meet this challenge?

Materials and Equipment:

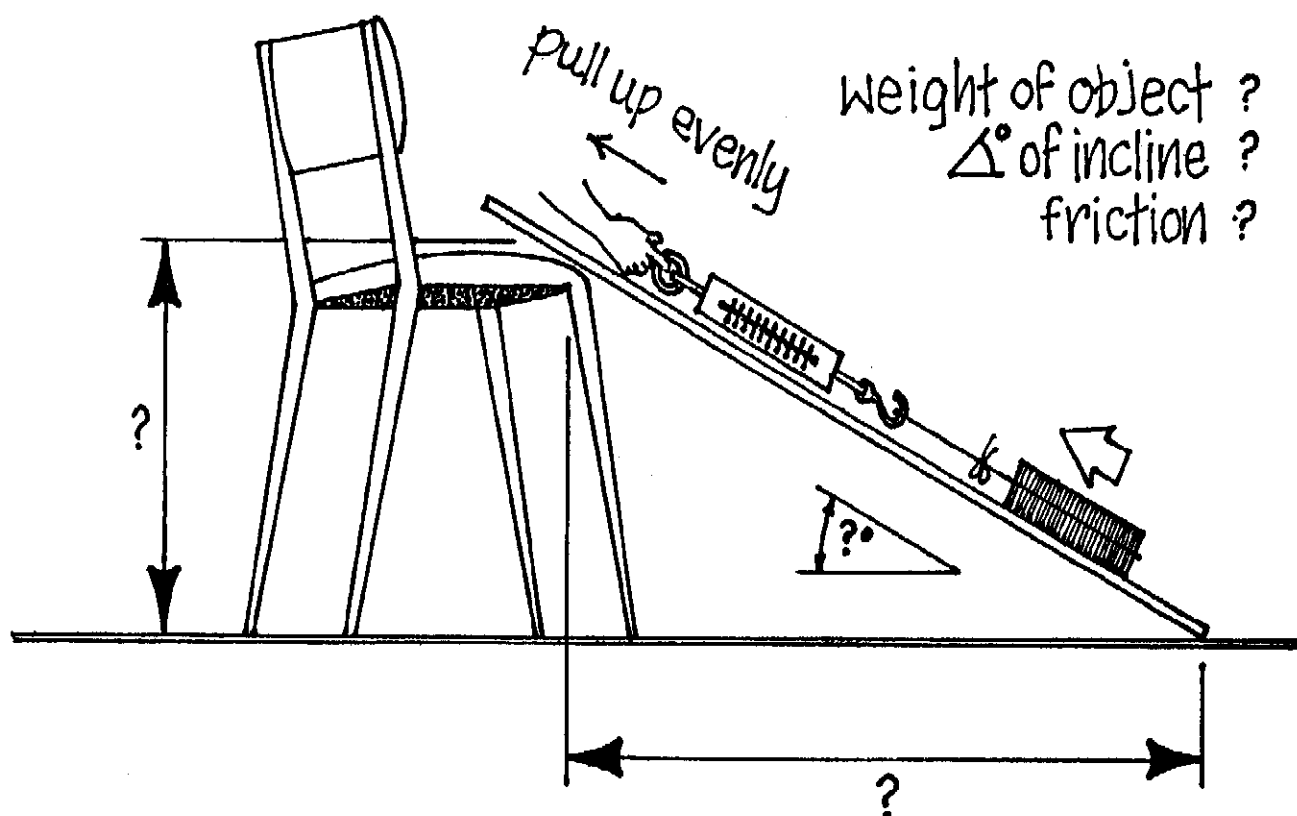
Spring balance
Brick or wooden block
String
Support
Several boards

Procedures:

Ask students a few questions related to ramps and inclines such as: Which way would you choose to push a shopping cart full of groceries up a very tall hill? A very steep path going directly to the top or a gently sloping path that zigzags up the side? Why?

The task of this investigation is to lift a block from the floor to a given height (such as the seat of a chair or the top of a desk). Ask students how they could complete this task and what equipment they might choose to use. Also ask them to speculate how they could use a spring balance to calculate the effort involved.

In our experience with this activity, most children do not choose the incline as an obvious way to raise the blocks. Many of them attempt to use a lever. While this does solve the problem, the pivot must be very high and the lever must be very long. A few students have even attempted to make a screw out of paper wrapped around a pencil while toying



with solutions. While a screw could also solve the problem, it would have to be very long to lift the load any substantial distance.

The method of choice for this investigation is the ramp, as shown in the drawing below. Explain to students that lifting the block straight up might be the simplest method, but it can be done with less effort. Effort can be measured by tying one end of a string to the block and the other to the spring balance with a loop. The effort is read from the spring balance as grams (dynes). Students will have to practice pulling the spring balance with a smooth even motion to be able to take a reading on the scale when the block is moved. As longer ramps are used, the amount of force needed to move the block decreases. Be sure in taking measurements of ramp length that students measure from the end of the ramp touching the floor to the point where the ramp makes contact with the chair or table. The length of the board is of no consequence unless it is at the height being measured. The table on the next page could be used as a guide for collecting data. The measurements shown are based on ideal measurements for lifting a 500 gram block. Actual measurements of force and therefore total work will be somewhat higher due to friction.

Students should discover that, as the slope of the ramp gets steeper, more effort is required to lift the load. As the slope of the ramp nears vertical, the amount of effort required to lift the load approaches the effort required to lift the load straight up. As the ramp becomes longer and less steep, less effort is required to raise the load to the same height. Students may notice, however, that the total work done is nearly the same for all arrangements. While effort decreases with a longer ramp, the total effort expended may actually seem to increase due to friction between the board and the load. In an ideal sense which disregards friction, the total work done is the same for all arrangements. In a

practical sense, more effort is really expended. Students measurements reflect effort expended rather than an ideal measurement of work as defined in physics.

While measurements made with this system are interesting, be sure that children have a chance to experience the feel of pulling a weight up ramps of differing length. A real understanding of how force changes as the slope increases may be better understood by how it feels than by interpreting a chart. The experience may actually give more meaning to such a chart.

Further Challenges:

- ☐ While less force is required to lift a load with a long ramp, what is the expense of this gain? (The longer distance it must travel.)
- ☐ Could you design an arrangement for raising the load that would further decrease the force required?
- ☐ Could other simple machines be added to this system to make a compound machine?
- ☐ Is it possible to create a system that requires less total work than the vertical lift? (No. Such a machine would produce perpetual motion.)

Height of ramp (cm)	Length of ramp (cm)	Force required to move load dynes (grams)	Total work done length x force = work (ergs or dyne-cm)
100 cm	100 cm	500 dynes	50000 ergs
100 cm	150 cm	333 dynes	50000 ergs
100 cm	200 cm	250 dynes	50000 ergs
100 cm	250 cm	200 dynes	50000 ergs
100 cm	300 cm	166 dynes	50000 ergs

Move It!

by Sue Dale Tunnicliffe

Focus:

The less friction there is, the easier it is (*less effort required*) to move a given load. This activity will help children experience this phenomenon.

Surface Separator	Effort required in dynes (grams)	Comments

Challenge:

How can you move an object more easily across a level surface without tipping the surface? What do you already know that will make it easier to move an object across a level surface? Is there any way you could separate the surfaces which would make it easier to move an object without lifting the object out of contact with the surface?

attach the other end of the string to the spring balance with a loop. They can now tape other materials (such as the sandpaper, cloth, polished wood, corrugated cardboard, pencils, or rods to use as rollers) to the working surface of the load to determine their effect on the force exerted by the spring balance. They may wish to record measurements and repeat the procedure several times for each surface tested. This will improve the accuracy of the results. The table above should aid in recording and interpreting data.

Materials and Equipment:

Books or Bricks Various work surfaces
Spring balance String
Masking tape

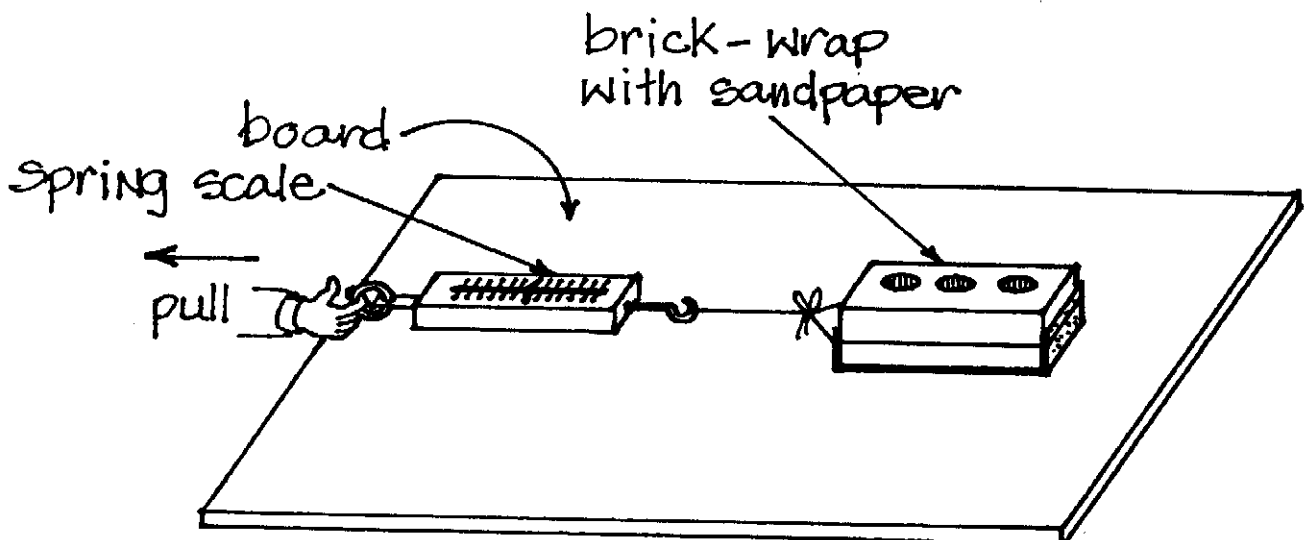
Students should discover that the smoother the sliding surface, the easier it is to move a load. This is due to the presence of less friction. If the load and the surface are separated by something such as a lubricant or rollers, the effort required to move the same load is less.

Procedures:

Students will select a load to pull that measures within the range of calibration of the spring balance. They should determine this with a few test trials of the surface of a table or the floor. They will tie the string around the load and

Further Challenges:

- ☐ Are there some methods of moving the load with less effort other than altering the surface?



When Slowest Is Best

by Thomas E. Thompson

Focus:

This activity gives students the opportunity to practice two science process skills *space-time relations* and *hypothesizing*. Students gain experience in *space-time relations* when they are challenged to get a marble to roll from one end of a table to another in the longest period of time. Simple calculations are then performed in order to introduce the concept of *rate of motion*, for example centimeters per second. After having some time for independent exploration of the materials, students will *hypothesize* how selected variables will affect the rate of the marble's motion.

Challenge:

What are the variables that will affect how fast a marble will roll across a given distance? What types of materials might you select to change the speed of a marble? What is the maximum time it takes for a marble to roll from one end of a table to another?

Materials and Equipment:

Marbles	Stopwatches
Long classroom tables	Paper
Rulers	Pieces of fabric
Tape	

Procedures:

This activity works best with groups of students around a table. Small cooperative groups work well. Students can be assigned various roles. Potential roles include the marble releaser, timer, recorder, and manipulating objects to slow the marble down.

Begin by explaining the task to be performed. Simply stated, a marble must roll from one end of a table to the other. A force may be imparted only once at the beginning when the marble is released. After the initial force is applied, the group must stand back away from the table and not interfere with the marble until it reaches the other end of the table. The length of time is measured for the marble to traverse the length of the table.

Students will likely try many approaches to solving this problem. Some examples that we have seen include: propping the table; placing paper, cloth, or water in the path of the marble; altering the marble itself; and positioning barriers similar to those found in a pinball machine. Students are also likely to try other unexpected and creative solutions to this problem. The important condition which must be maintained is that once the marble is placed in motion, everyone must stand back and not intervene until the marble drops off the opposite end of the table.

Friendly competition is inevitable. However, the nice part of this activity is that the focus is on the slowest marble rather than the fastest. Potential discipline problems are held to a minimum.

When groups begin to test their hypotheses, modifications of their original ideas become frequent occurrences. Be prepared for this activity to take at least an hour or more of class time.

Further Challenges:

☐ A natural extension for this activity is to have the children compute the time it would take their marble rolling at "X" centimeters per minute or hour to roll different distances. For example, how long would it take to go from one end of the school to the other? How long would it take to traverse the length of the playground? How long would it take to travel from their home to the school building?

☐ Similar comparisons could also be made between groups whose marbles rolled different speeds.

☐ Other comparisons could be made with various animals found in the classroom or outdoors (i.e., turtles, mealworms, goldfish, sowbugs, ants, etc.).



All Geared Up

by Janet Frekko

Focus:

Gears were probably used in Egypt and Babylon in clocks and lifting equipment 3,000 years ago. The Chinese may have used gears even as long ago as 5,000 years. At any rate, this modification of the simple wheel has been around for a very long time. Gears are used in almost all of our machines transferring motion from one part to another. Gears can speed up or slow down a machine as well as change the direction of the motion. The following activities use simple, inexpensive materials to show how gears work.

Challenges:

What happens to the direction of the rotation of each gear when two gears are meshed together? What happens when two gears are separated and turned as a unit by a band or a chain as with a bicycle? How does the size of each gear affect the number of rotations?

Materials and Equipment:

White glue

Scissors

Paper clips

Corrugated paper (apx. 3 cm x 150 cm)

Styrofoam meat tray (apx. 12 x 18 cm)

Pencils

Rubber bands

Plastic straws

Tape

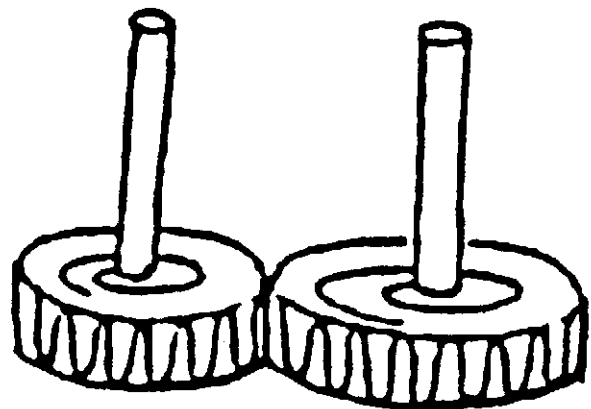
Procedures:

The children will construct two gears each mounted on a straw shaft. One gear will be twice the diameter of the other. The gears are made from light weight corrugated paper. It is available in 2.25" x 50 ft. rolls generally used for trimming bulletin boards. It is also available in 4 ft. x 5 ft. rolls. The cuts must be made across the grooves as

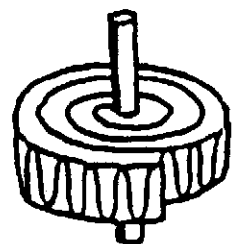
shown in the illustration at the bottom of the page. Use the cutting guide on the back of the paper.

Give each child a 30 cm by 3 cm piece of corrugated paper cut across the grooves. Older students may be able to do their own cutting. Cut a 20 cm straw in half. Make a mark on the straw one cm from the end. Tape the end of the corrugated paper (*grooved side out*) to the straw at the mark so that the end of the straw is sticking out 1 cm past the paper. Roll the 30 cm length of paper around the straw (*jelly roll fashion*) to make a gear. Glue the last 2 cm. Secure the roll with a rubber band to hold in place until the glue dries.

Make a second gear as above using a 1.5 meter by 3 cm piece of corrugated paper and the other half of the plastic straw.



Measure the diameter of each gear. The smaller gear should be approximately 3 cm in diameter and the larger gear should be approximately 6 cm in diameter. Adjust the tightness of the roll as necessary. When the glue is dry, remove the rubber bands. Hold the gears next to each other as shown above with the gears of one meshed to the other.

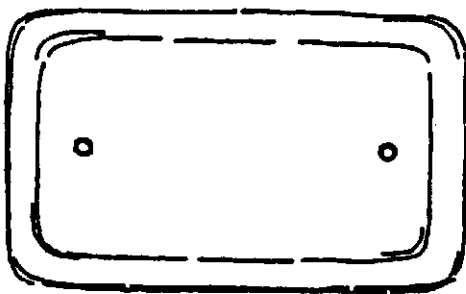


Turn the straw shaft of the larger gear while in contact with the smaller gear. In which direction does each turn? (*The opposite direction from each other.*)

Give each child a meat tray. Place the meat tray upside down on the table. Using a pencil, poke a hole 3 cm from each end of the meat tray as shown below. The hole needs to be large enough to fit a straw into snugly. Fit the gears onto the meat tray with the 1 cm piece of straw going through the meat tray toward the table. There will be 8-12 cm of space between the two gears.

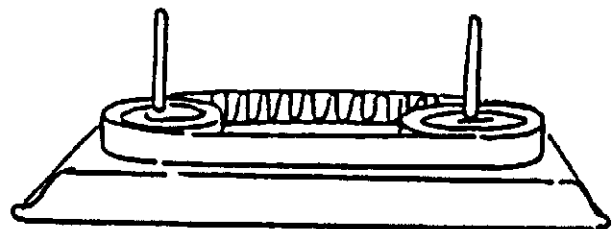
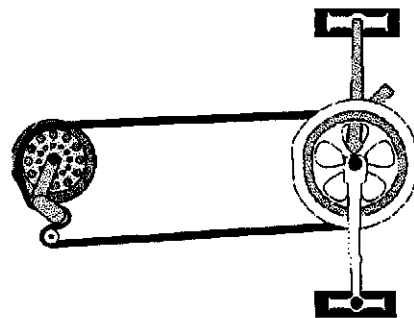
With another 3 cm wide strip of corrugated paper (*again cut across the grooves*) the children will simulate a bicycle chain. With the corrugated side next to the gears, place the paper around the two gears. Attach with a paper clip so that the chain may be adjusted. Turn the larger gear by rotating the straw shaft. (*This would be the pedal end of a bike*) What happens? The chain causes the other gear to turn. Notice that the gears are turning the same direction. The chain causes the direction of both gears to be the same.

With the chain still in place, make a mark on each of the gears and a corresponding spot on the tray. Rotate the larger gear $1/2$ turn. Where did the second gear stop? Now try one full turn. (*If our corrugated paper rolls were accurate one full turn of the large gear would equal two turns of the small gear.*) Old fashioned bicycles, like the ones with the giant wheel in front, got speed by using a big wheel. Peddles would go around once and the wheels would go around once. Modern bicycles get the same speed using smaller wheels by using a gear to make the wheels turn more often.



Further Challenges:

- ☐ Examine a bicycle. Compare a 3 speed to a 10 speed bike. What happens as you change gears?
- ☐ Bring in several simple kitchen or shop tools or children's toys which use gears. Examine closely the ways in which gears are used.
- ☐ Explore gear ratios and have the children do some calculations.
- ☐ Take a look at various types of gears. When are spur gears, helical gears, bevel gears, worm gears, planetary gears and rack and pinion gears used?



USING SIMPLE MACHINES

by Thomas E. Thompson

Focus:

This activity serves a dual purpose in the area of simple machines. The primary focus is as a culminating activity which provides young children with the opportunity to apply previously learned concepts about selected types of simple machines. It also could be used as a mechanism for evaluating students understanding about simple machines and selected process skill acquisition.

Challenge:

Select the most appropriate simple machine from a large group of simple machines in order to successfully complete a prescribed task in the shortest amount of time.

Materials and Equipment:

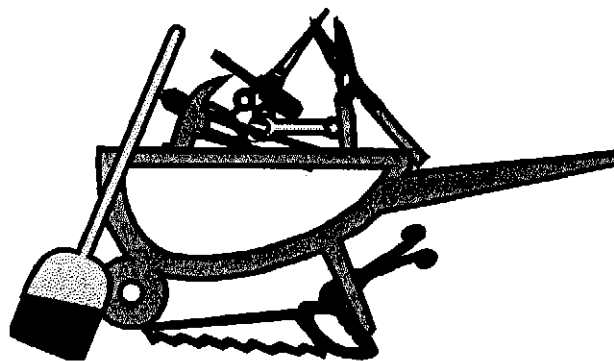
Paper punch	Tweezers
Scissors	Screwdriver
Pliers	Wire cutters
Six foot wooden plank	Staple remover
Wooden dowels (2 cm)	Tongs
Hammer and nails	Stapler
Wooden dowels (5 mm)	Long nose pliers
Other assorted items	Pencil sharpener

Procedures:

This activity works best if you divide the class into small cooperative groups. Each group will be able to select from the same set of simple machines. You may wish to ask students to bring items from home for the collection.

Define a specific task to be performed each group. Initial task might be using a simple machine to remove four paperclips from a baby food jar. While one student actually performs the task, the group will help to plan the strategy for solving the problem. The person actually carrying out the task should change for each challenge. Each group will attempt to complete the task in the shortest possible time.

A point system might be used to keep a running total score for each group. For example, a group may receive a point if the most appropriate simple machine is selected. A second point might be awarded for successfully completing



the task. A third point may be awarded for completing at task in under than a minimum amount of time.

When the activity is completed, discussion should focus on which simple machine was best for a particular task. This activity could also be used to evaluate students' grasp of information previously presented on simple machines.

Further Challenges:

- ☐ Make an eight cm diameter hole in a piece of paper.
- ☐ Make a one cm diameter hole in a sheet of paper.
- ☐ Fasten four sheets of paper to form a square.
- ☐ Remove a staple from a set of stapled papers without tearing the papers.
- ☐ Make a triangle from three tongue depressors which will stay intact when picked up.
- ☐ Remove four marbles from a wide mouth canning jar.
- ☐ Separate a paperclip into three equal sections.
- ☐ Lift a heavy box of books up to the seat of a chair.
- ☐ Move box of books from one side of a room to the other.
- ☐ Sharpen a five mm wooden dowel.
- ☐ Ask the children to design additional tasks.

CHAPTER - 8



TAKING THE HEAT

by David R. Stronck

Focus:

A calorie is the amount of heat needed to raise the temperature of one gram of water by one degree Celsius. Foods give off calories when we digest them or when we burn them.

Challenge:

Which kind of food is the richest source of calories?

Materials and Equipment:

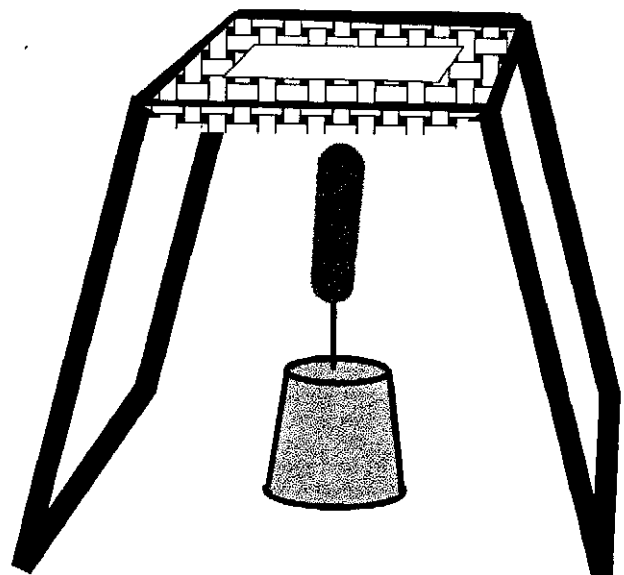
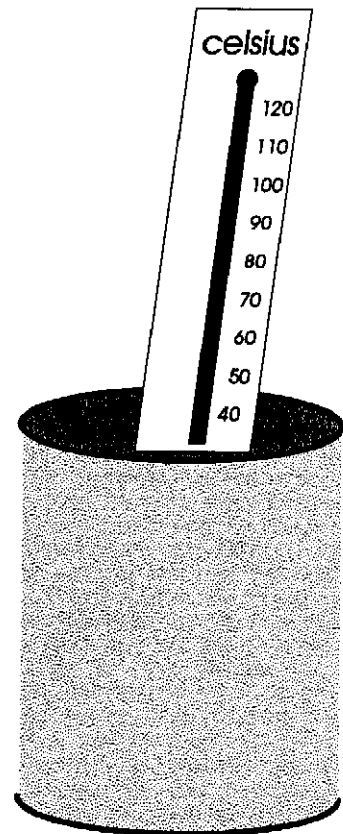
Aluminum window screen	Wire coat hangers
Pliers	Pocket knife
Small "tin" cans	Corks
Needles	Celsius Thermometers
Balances	Matches
Tape	Cheese curls
Small marshmallows	Water

Procedure:

Before the lesson begins, prepare the coat hangers to serve as platforms for holding the can with water. Use pliers to bend the coat hangers. Wire coat hangers have two parts: (1) the top hook that fits over a rod and (2) the bottom loop that fits into the shoulder area of clothes. Start by cutting off the top hook. Bend the loop into a shape like the one shown on this page. Now the bottom loop can be placed on a table top and will stand upright. Use a piece of tape to connect the ends of the loop. Next cut a piece of aluminum window screen to fit the top section of the platform. Cut a small hole in the middle of the screen. *Later this hole will allow the flame to touch the can directly.* Bend the ends of the window screen around the top of the clothes hanger as shown. Adjust the shape of the holder until it will support a small can full of water.

Ask the students what they know about calories. If necessary, explain to them that a calorie is a measurement of the heat energy that is contained in foods, fuels, etc. We can measure the amount of calories available in a variety of foods and can test which foods give the richest source of calories. The following procedures will allow students to conduct investigations into the calorie content

of various foods. Dry foods such as nuts, snack foods, toast, etc. work best for conducting these calorie tests. While this device is not as accurate as a commercial



calorimeter, it does give good relative comparisons among foods tested.

Begin by weighing an empty can. Record this weight. Add 100 grams (100 ml) of water to the can. Place the can with water on the coat hanger platform. Directly below the can place the upright cork with a needle stuck in it. Weigh each food item before using it and record this weight. At the top end of the needle stick the selected food, e.g., a cheese curl.

Place the thermometer in the water in the can. Record the starting temperature. Strike a match and use the flame to begin burning the food at the top of the needle. Allow the food to burn as completely as possible. Gently stir the water with the thermometer while the food is burning. Record the final temperature. Subtract the starting temperature from the final temperature to calculate the temperature change. The 100 grams of water has changed by this number of degrees. Since a calorie is the amount of heat that changes one gram of water by one degree Celsius, the number of degrees of temperature change is multiplied by 100 to give the number of calories that were generated.

Use this simple formula to calculate calories.

$\text{Change } ^\circ\text{C} \times 100 \text{ g of H}_2\text{O} \times \text{calories} = \text{calories from the food}$

The data recorded above allows us to calculate the calories from burning each piece of food. The samples of food probably have different weights. Now we need to divide the total number of calories given off by each food sample by the weight of the food sample. This calculation will give the calories per gram of the food. Finally, we can compare these calories per gram of each food to recognize which food is the richest source of calories.

Further Challenges:

☐ Invite the students to test many other foods for their caloric content.

☐ Note that the "food calorie" described in books equals 1000 scientific calories (as we calculated in this activity.) Consult with various books on nutrition about the calories in various foods. Compare the answers in books with results done by the students' measurements. Why are there differences?

Investigating Color And Heat

by Tom Graika

Focus:

Stepping barefooted from a lawn in the summertime onto a blacktop road can be a painful experience. The road feels hotter than the lawn felt. The color of objects is one of the factors that seems to determine how much heat is absorbed. A black car in the sun seems hotter to the touch than a white car.

Challenge:

How does the color of a liquid effect how much heat is absorbed?

Materials and Equipment:

Several containers
Thermometers
Sunny Window Ledge (or heat lamp)

Food coloring
Water

Procedure:

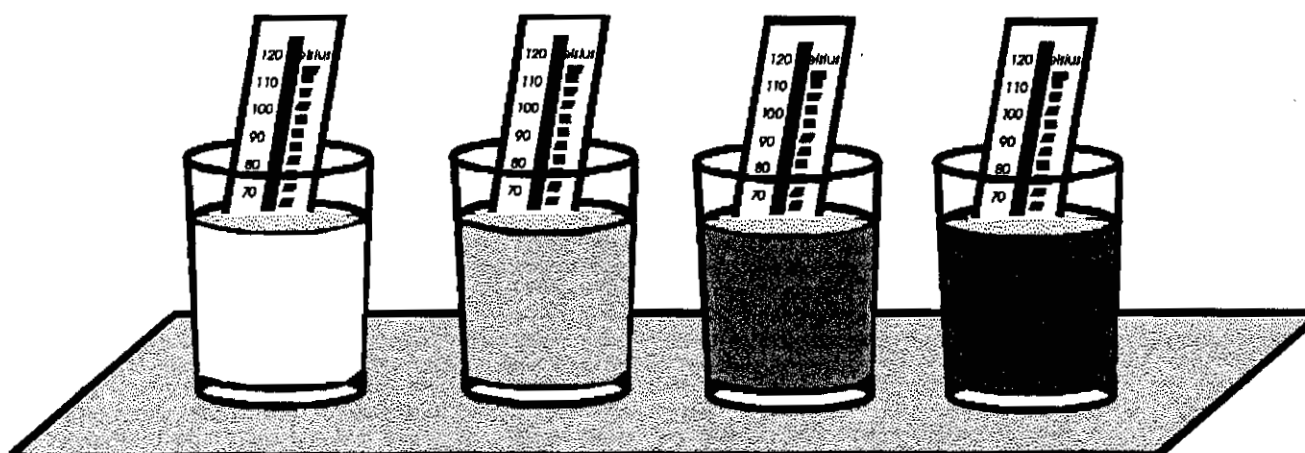
Place the same amount of water in several containers of the same size. Place 10 drops of food coloring in one of the containers and stir until the color is evenly distributed in the water. Prepare the other containers in the same manner using different colors of food dye.

Place the containers on a sunny window ledge or an equal distance from a heat lamp. Place a thermometer in each of

the containers and record the temperature. Allow the containers to stand in the heat for 30 minutes. Record the temperature in each container at the end of the 30 minutes. Determine which color absorbed the most heat. Determine which color stayed the coolest. Try to determine a pattern, if any, between color and heat absorption.

Further Challenges:

- ☐ Find out how much heat plain water absorbs compared to colored water.
- ☐ Find out how much heat is absorbed by different colored liquids such as grape juice, orange juice, cherry pop, or tomato juice.
- ☐ Find out if keeping liquids in a heat source for twice as long will double the amount of heat that is absorbed.
- ☐ Keep track of heating liquids by taking temperatures every five minutes and preparing graphs of the heating rates.
- ☐ Use colored construction paper and thermometers to find out if colored solids absorb heat the same way colored liquids do.



HOW MUCH TIME?

by Patsy Ann Giese

Focus:

Particles of matter (*atoms and molecules*) move further apart when heated. Therefore, water becomes less dense when heated. More dense cold water, pulled down by gravity, pushes up the less dense hot water. This motion is called a convection current. When two sections of water are the same temperature, and therefore the same density, there are no convection currents. Mixing occurs only by diffusion, which is considerably slower than mixing by convection.

Challenge:

Predict how long convection and diffusion take. Check predictions with observations.

Materials and Equipment:

Bottles with flat rims

Water

Food coloring

Hot pads or gloves

Plastic playing card

Procedure:

Fill two bottles to the same level. One will be filled with hot water, the other with cold. So that the two bottles can be distinguished later, label the bottles "hot" and "cold" or add two different colors of food coloring to the bottles. Mark the water level on each bottle with tape or a marker. Cover the bottles with plastic wrap to prevent evaporation. Let the bottles cool to room temperature, perhaps overnight. Have students check the water levels and discuss the observed changes. As hot water cools, particles move closer together causing the water level to drop. As cold water warms, particles move farther apart causing the water level to rise. (*See the exception discussed below in the last part of "Further Challenges."*)

Color a pot of hot water yellow and a pitcher of cold water blue then fill two bottles with hot water and two bottles with cold water. Have students predict what will happen when you invert a hot bottle over a cold and a cold bottle over a hot. Have them include in their prediction an estimate of the time required for changes to occur. Perform the experiment, but before inverting a bottle cover it up with a card to prevent spilling water. After that bottle is in

place on top of another bottle, gently pull the card out. Discuss any discrepancies between students' predictions and the experimental results.

In a few minutes, the water will be green in the bottles where cold water was placed over hot water. Many students will predict that the water in the other pair of bottles will be green when the bottles reach room temperature. However, at room temperature, only diffusion is occurring; mixing completely by diffusion may take more than a month.

Further Challenges:

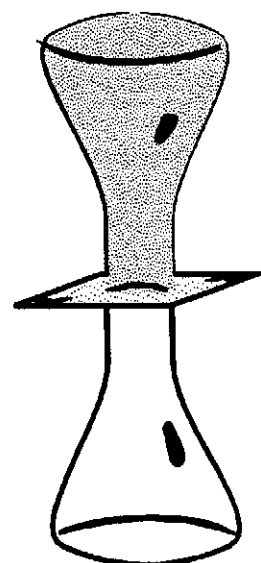
☐ Discuss which bottles have more water molecules in them when completely full. Will it be the bottles with cold water or the bottles with hot water?

☐ Float an ice cube of colored water in a larger container of hot, clear water. Have students observe the movement of the cold water formed from the melting ice.

☐ Ask students if they have ever felt the water get colder as they dived deeper in water. Discuss the decrease of temperature with increasing depth in a lake or an ocean.

☐ Discuss the movement of warm and cold ocean currents.

☐ Explain that, although most substances contract when cooled, water expands when cooled from four degrees Celsius to its freezing point at zero degrees Celsius. Discuss how this fact is related to the formation of ice on the tops of lakes as very cold water rises instead of sinks. Discuss why life might not exist in lakes if ice formed on the lake bottoms.



Measuring the Heat

by Mark R. Malone

Focus:

A thermometer is a simple device for measuring temperature. This activity concretely demonstrates how expansion and contraction of a liquid are applied in this device.

Challenge:

Describe how expansion and contraction are responsible for the working of a thermometer.

Materials and Equipment:

Water or rubbing alcohol	Food coloring
Hot pads or gloves	Flask
Glass tube (apx. 30 cm long)	One hole stopper
Tape	

Procedure:

Discuss why the liquid in a thermometer takes up more space on a hot day compared to a cold day. This could be related to the previous activity. Make a thermometer by inserting a glass tube about 30 cm long into a one hole rubber stopper. Fill a flask with colored water or rubbing alcohol, and seal the flask with the rubber stopper. Add enough liquid so that part of the glass tube is filled. Place a piece of tape on the tube to mark the height of the liquid. Heat or cool the flask and observe the change in the height of the liquid in the tube.

Further Challenges:

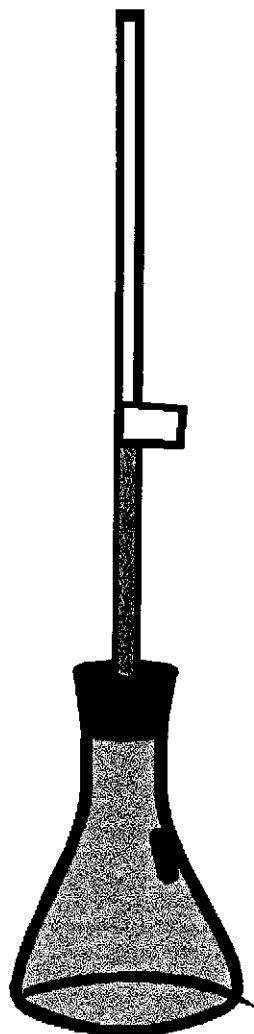
☐ What would happen if the tube were heated and the water was not allowed to expand up the tube? (*The flask might eventually explode.*)

☐ Observe the water in the tube just as it is placed in hot water or cold water. Note that the liquid initially drops and then rises when heated. It also rises and then falls when cooled. Why does this happen? (*The flask expands with heat and cools with cold before the liquid inside of it expands or contracts. This discrepant event can also be seen when a commercial thermometer is placed in hot or very cold water.*)

☐ Why are liquids such as alcohol or mercury used rather than water in thermometers?

Safety:

Before inserting the glass tube into the rubber stopper, wet the glass tube with water or lubricate it with petroleum jelly. Hold a paper towel around the glass tube to protect your hands in case the glass tube might break. Twist the glass tube as you insert it, not applying excessive force. It is advisable to use safety goggles anytime when glass is heated or cooled.



Rising Heat

Mark R. Malone

Focus:

Hot water when placed into a body of cooler water will rise through the cold water. This flow of hot water through cold is called a current.

Challenge:

Observe what occurs when warm water is released into a container of cold water.

Materials and Equipment:

Water	Food coloring
Hot pads or gloves	Clear pill vials
Flask	Two hole stopper
Glass tubes (apx. 5 cm long)	string
Tall clear container	

Procedure:

Select a two hole stopper that will fit snugly into a plastic pill vial. Place short pieces of glass tubing into the stopper as shown. Pour colored hot water into a pill vial. Tie a string around the top of the vial. The string is used to lower the vial at the bottom of a large container of clear cold water. It also helps to keep the vial from tipping over when it reaches the bottom.

Have students observe the movement of the hot colored water. Repeat this activity, except put cold colored water in the vial and put hot clear water in the larger container.

Note: A two or three liter bottle with the top cut off might serve as the large container.

Further Challenges:

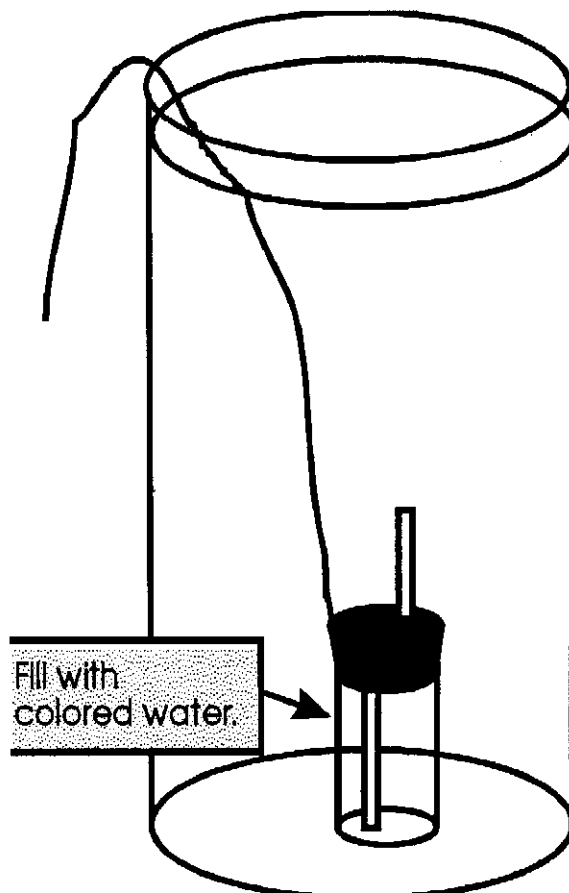
- ☐ Why does the hot water rise to the top of the large container of cold water?
- ☐ Why doesn't the cold water rise to the top of the large container of hot water?

☐ How does this activity relate to air's behavior in the environment? (*Hot air from a smokestack rises in a plume on a calm cold day.*)

☐ How does this activity relate to weather phenomena? (*Warm air rises through cold in many weather situations. It is a factor in many weather events such as in warm fronts, regional wind, global circulation patterns, low pressure systems, etc.*)

Safety:

Before inserting the glass tube into the rubber stopper, wet the glass tube with water or lubricate it with petroleum jelly. Hold a paper towel around the glass tube to protect your hands in case the glass tube might break. Twist the glass tube as you insert it, not applying excessive force. It is advisable to use safety goggles anytime when glass is heated or cooled.



Supercooling

by Michael J. Demchik

Focus:

Supercooling or dropping the temperature to various positions below the normal freezing temperature of liquids or solutions can take place in special freezing mixtures.

Challenge:

Can you explain why samples of liquids or solutions fall below their normal freezing temperature, yet don't freeze? How low can you get temperatures of liquids or solutions by conventional methods without having them freeze? What are some methods used to drop the temperature that do not involve the use of chemicals?

Materials and Equipment:

Ice	Water
Salt	Acetone
Various salt water solutions	Alcohol
Thermometers	Test tubes
Beakers	

Procedure:

Prepare four test tubes of distilled water. Put a clean thermometer into each test tube. Place each test tube in the following four beakers containing the listed mixtures.

1. Beaker - ice
2. Beaker - ice and salt
3. Beaker - ice, salt and alcohol
4. Beaker - ice, salt, alcohol and acetone

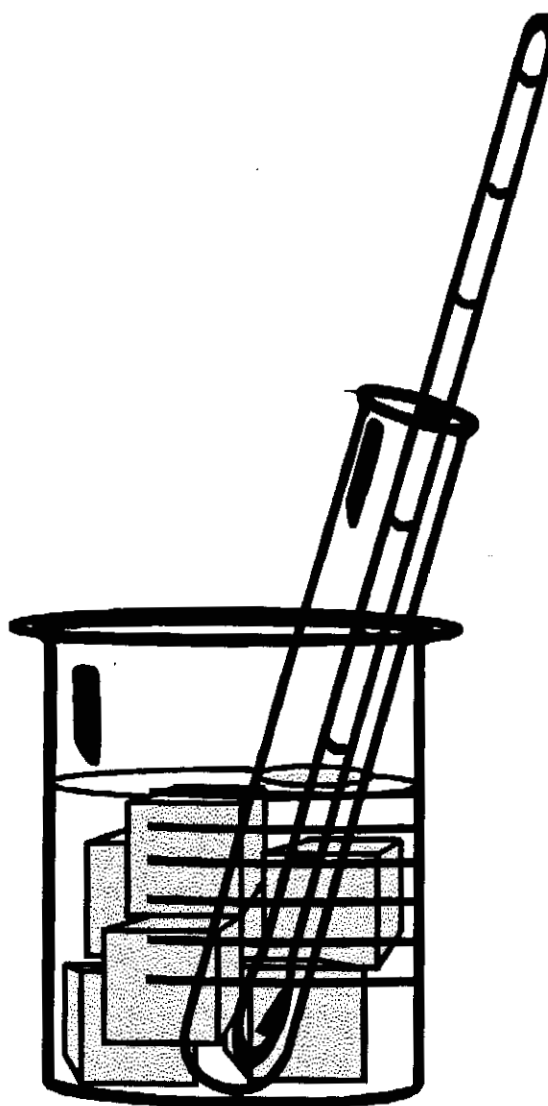
Allow to stand for several minutes. Allow students to observe and record initial results. The observation and recording should continue until the temperatures fall below the normal freezing point of water. Have students remove the test tube and shake slightly. At this point the supercooled solutions will freeze rapidly.

Further Challenges:

- ☐ Prepare various strength solutions of salt and ice in the test tubes. Repeat the same procedure.

- ☐ Collect temperature data every 30 seconds and plot the results.
- ☐ What effect does the presence of salt in the water have on the freezing temperature of the water?
- ☐ Try other materials such as calcium chloride.

Safety: Whenever chemicals are being used, be sure to consult container labeling for safety precautions.



Soda Cans That Blow Bubbles

by Lawrence D. Calhoun

Focus:

When a gas is heated in a *closed systems*, it results in increased pressure. The opposite is true for gases that are cooled.

Challenge:

How can you make a soda can blow bubbles?

Materials and Equipment:

Aluminum soda cans	Soap bubble solution
Aluminum pie pans	Rubbing alcohol
Cotton balls	

Procedure:

Divide the class into small groups. Give each group an empty soda can container of soap solution, some cotton balls, and a paper cup filled with rubbing alcohol. Ask students to respond to the following questions and statements.

Is the soda can an open or closed system?

If we dip the open end of the can into the soap solution, a soap film will cover the soda can hole. Is it still an open system?

What do you think will happen now if we heat the air inside the closed system can?

What would happen if we cooled the air instead?

Using just your hands and the materials in front of you, how could you heat and cool the air inside the soda can?

Students should discover that rubbing their hands briskly together creates heat from friction. They should discover that a cotton ball dipped in alcohol and spread on their hands results in cooling. Blowing or fanning creates even more cooling as a result of the evaporation process. Now ask students to apply their heating and cooling techniques gently to the soda can. Students should observe results similar to those seen below.

The concepts developed here apply to CLOSED SYSTEMS. When air is heated in a closed system, the air expands and an increase in air pressure results. When air is cooled in the closed system, the air contracts, takes up less space. As a result, the air pressure becomes less than that of the outside surrounding air. The bubble being blown larger by the can being warmed by the rubbed hands shows this well. The bubble being pressed in on the cooled can also shows clearly the contraction of a cooled gas.

Further Challenges:

- ☐ Encourage students to study the effects of different degrees of heating. (*e.g., number of times the hands are rubbed together*)
- ☐ Encourage students to study the effects of different degrees of cooling. (*e.g., fanning and no fanning of alcohol*)
- ☐ Everyday events to help support the concept include: bicycle tires or basketballs "swelling" on a hot day; a helium party balloon "shrinking" when taken outside on a winter day; and aerosol cans exploding in an incinerator, etc.

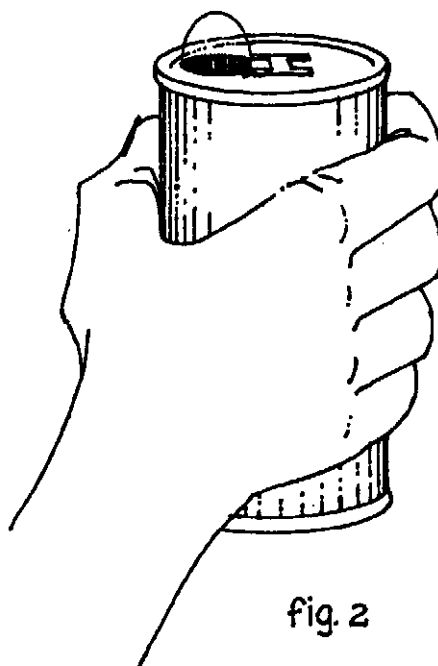


fig. 2

Balancing the Heat

by Lawrence D. Calhoun

Focus:

When gases are heated they expand and become lighter in *open systems*. When gases are cooled, they contract and become heavier in *open systems*.

Challenge:

How can two identical empty paper bags have different weights?

Materials and Equipment:

Paper lunch bags	String
Scissors	Tape
Meter stick	Balance rod
Clay or wax candle	Matches
Plant mister	Fire extinguisher
Bucket of water	

Procedure:

Balance two identical paper lunch sacks as shown below. Since an open flame is used, teachers should probably do this activity as a demonstration. Spray paper bags with a plant mister before balancing them. Some balancing tips include: letting some wax from a small birthday candle drip on the "lighter" bag after you've tried to rough balance the two bags, moving the string loops closer or farther from the center of the suspended meter stick as seen in the drawing

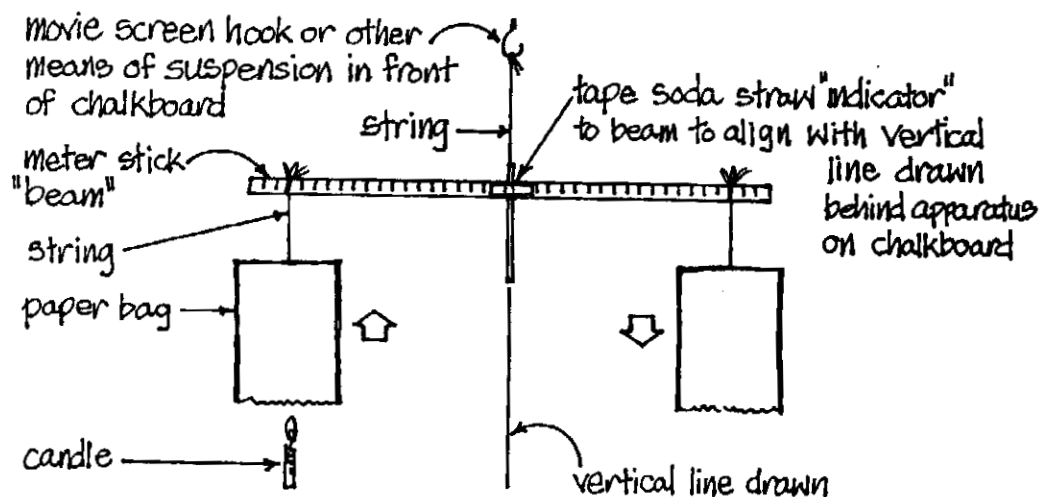
below, and adding a pinch of modeling clay to the lighter side of the meter stick.

After the class decides the bags are perfectly balanced (the soda straw indicator should align with a perpendicular chalk mark on the board), ask what the class thinks: Do both bags contain the same amount of air? Could we call these *open systems*? Why? What do you predict will happen if we carefully hold a small burning candle under one of the bags? Why?

Next the candle is lit and placed under one of the bags. The class observes as the heated bag rises and the unheated bag drops. Students should be asked to speculate as to why this occurred.

Further Challenges:

- ☐ Ask students to name other examples of this phenomenon. (e.g., hot air balloons, smoke rising, chimney drafts, etc.)
- ☐ Students should be led to a formal summary of related phenomena such as: when air is heated in an open system, the air expands and some escapes causing it to weight less. An identically sized container system which is not heated contains more air and is therefore heavier.



Safety: Stress safety by having a fire extinguisher and a bucket of water handy while conducting this demonstration. Be careful not to let the candle come too close to the paper bag.

Balloon In the Bottle

by Mark R. Malone

Focus:

When a gas is heated or cooled it will expand and contract respectively.

Challenge:

How can a water balloon be moved into a wine carafe?

Materials and Equipment:

Wine carafe
Water

Balloons
Paper towel

Procedure:

Most teachers are familiar with the "egg in the bottle" demonstration. In this old "Mr. Wizard" activity a hard-boiled egg is put in an old fashioned milk bottle without pushing it through and smashing the egg. The trick is to quickly drop a burning piece of wound up paper towel into the milk bottle and quickly setting a shelled, hard-boiled egg on the bottle opening. The effect is almost instantaneous and quite dramatic with a loud accompanying plunk. The greater outside air pressure pushes the egg into the bottle where the burning paper has rapidly expanded the air with some air escaping around the edge of the egg. This is followed by a quick drop in pressure as the air inside the bottle quickly cools and contracts as the flame is extinguished by the egg cover.

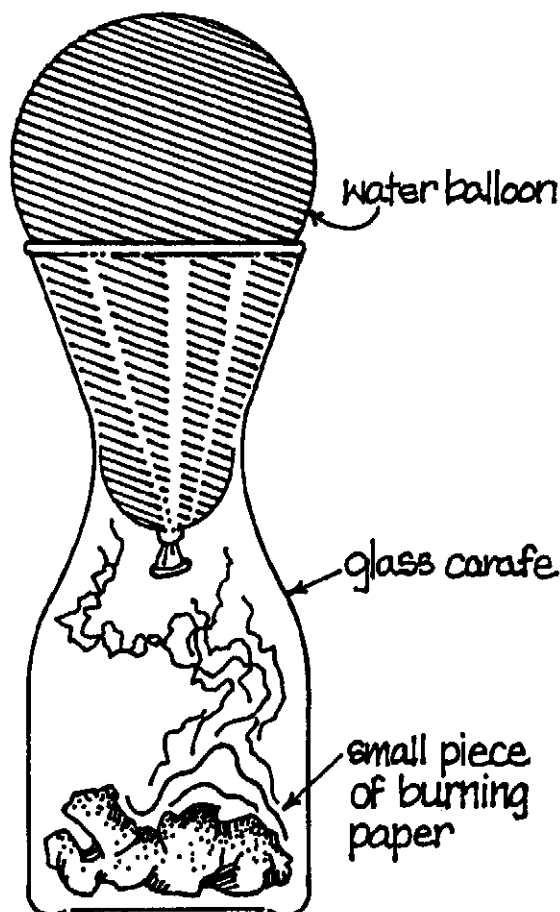
Since "old fashioned" milk bottles are being sold at high prices as antiques, the wine carafe and water balloon are a more convenient substitute. Begin by filling a balloon with water. The balloon should be slightly larger than the opening of the wine carafe. Next wind up a small piece of paper towel, light the end, and drop it into the wine carafe. Quickly place the water balloon on top of the carafe's opening.

Ask students to observe what happens and speculate as to why it occurs. Initial responses are typically related to the flame burning up oxygen and decreasing air pressure. This "of course" is not true. While oxygen is used for combustion it is merely changed in form, not consumed. In a burning reaction, matter is neither created nor destroyed.

It is merely changed in form. Student's attention can be drawn to the correct conclusion by having them focus on the sequence of events as they occur. Particular attention might be called to the water balloon as it bounces up and down before being pushed into the carafe. It acts as a one way valve allowing expanding air to escape but preventing it from reentering the bottle.

Further Challenges:

- ☐ Ask students to observe and describe the entire series of events which occur before and after the balloon enters the bottle.
- ☐ Ask students to suggest other types of containers that might work for this demonstration.
- ☐ Ask students to infer how this activity is similar to the previous activity, *Soda Cans That Blow Bubbles*.



Hot And Cold And Up And Down

by Patsy Ann Giese

Focus:

Particles of matter (*atoms and molecules*) move further apart when heated. Therefore, air becomes less dense when heated. More dense cold air, pulled down by gravity, pushes up the less dense hot air. This motion is called a convection current.

Challenge:

Observe evidence and infer that hot air rises while cold air sinks.

Materials and Equipment:

Shoe box	Aluminum foil
Plastic wrap	Packaging tape
Two glass lamp chimneys	Candle
Modeling clay	Matches
Cotton rope	Ruler
Cotton thread	Hot plate
Paper streamers	Shallow pan
Water	

Procedure:

Take off the top of the shoe box and cut a large window in it as shown below. Cover the opening with plastic wrap and tape it in place. Next cut two holes in the one side of the shoe box as shown. The holes should be the same diameter as the bottoms of two glass chimneys. The entire interior surface of the box should be lined with aluminum foil as a safety precaution.

Place a lighted birthday candle directly beneath one of the holes. A piece of modeling clay could be used to help stand the candle. Gently replace the lid of the box. Place two lamp chimneys in the top over the holes. Use a match to light the end of a short piece of cotton rope. After it has burned for a few seconds, blow out the flame. Hold the smoking rope over first one chimney and then the other. Have the students observe motion of the smoke. Discuss why smoke moves up over the candle and down in the other chimney.

Repeat this activity immediately after extinguishing the candle. Repeat it again after all the air in the box has cooled.

Further Challenges:

☐ Separate a piece of cotton thread (seven or eight cm long) into the fine strands that make up the thread. Tape one end of these threads to the end of a ruler. Hold the threads over a hot plate, below and above an open refrigerator door, below and above an oven door.

☐ Ask students where the coldest part of a refrigerator is.

☐ Ask students why cold air stays in open chest freezers at grocery stores.

☐ Ask students where the hottest part of an oven is.

☐ Ask students why candles are placed below, not above, food in chafing dishes and fondue pots.

☐ Threads or thin paper streamers can be used to detect movement of air in and out of windows. When the temperature is hotter outdoors than in the room, check the direction of motion in front of the highest window opening in the room and in front of the lowest window opening. All other windows in the room should be closed. Repeat this activity when the temperature is colder outdoors than in the room.

☐ Have each student hold one hand above a shallow pan of hot water and one hand below. The two hands should be equal distance from the water. Have students state which hands feels warmer.

☐ Bring to class a decoration in which a pinwheel turns above lighted candles. Discuss how the decoration works. Have students make pinwheels and hold the pinwheels over hot radiators. (They can cut a square of aluminum foil 7.5 cm on a side and then cut along each diagonal to within 1 cm of the center. They should fold back every other point to the center and insert a straight pin through these corners, the center of the foil, and finally into a pencil eraser.)

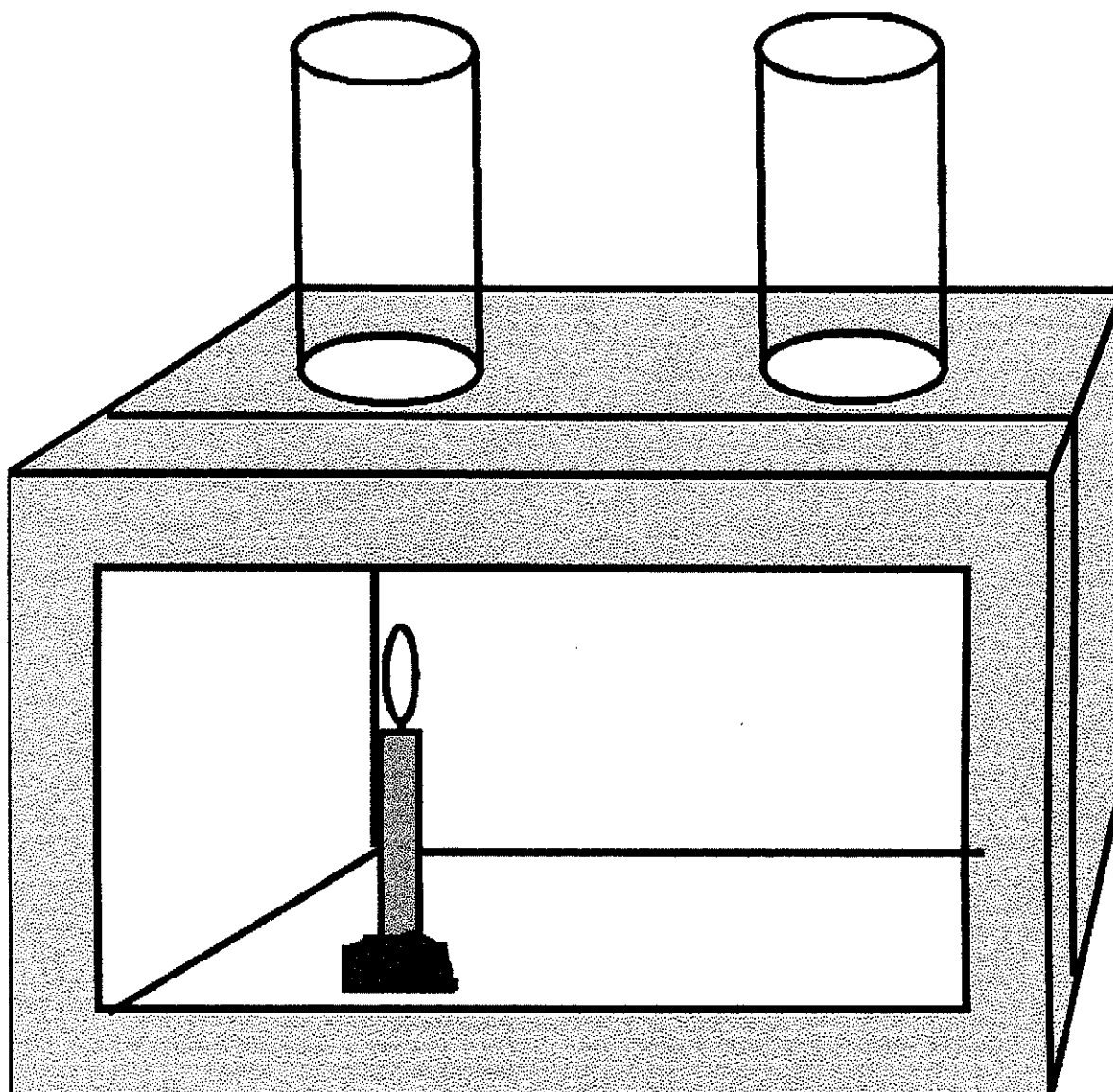
☐ Discuss the distribution of heat throughout a room by convection currents. At home, have students check the locations of radiators and the locations of gratings for hot air ducts and cold air returns. Discuss which rooms are usually hotter, those on an upper story or those on a lower story. Have each student explain any other places consistently warmer or colder than the rest of his/her home. Possible reasons are distance from the furnace, number of radiators, number of windows, and amount of insulation.

☐ Discuss the reason why operating ceiling fans can reduce heating costs in home. The fans can make a room, particularly one with high ceilings, feel warmer to a person sitting in the room because the fans force warm air downward.

☐ Discuss why smoke from a campfire rises instead of sinks. Discuss why firemen sometimes crawl out of rooms containing smoke.

☐ Discuss weather phenomena, such as major air currents, cold / warm fronts, and sea / land breezes, in which cold air sinks beneath warm rising air.

Safety: Stress safety by having a fire extinguisher and a bucket of water handy while conducting this demonstration. Be sure the threads are well above the hot plate so they do not burn. Be sure no child is burned by a candle flame, hot plates, or by hot wax dripping from a candle.



Fizzbubblepop (Fast Getaways)

by Terri G. Switzer

Focus:

Soda pop gets its fizz from carbon dioxide gas. Carbon dioxide is added to the soda before the bottle is sealed. As soon as you open a carbonated soda, the gas starts to escape. Tiny bubbles filled with carbon dioxide gas pop and tickle your face when you drink the soda. But, carbon dioxide is odorless and colorless. Students must use other senses to detect evidence of this gas. They can feel and measure carbon dioxide when it is trapped in a container such as balloon.

Challenge:

What do you think causes a soda to lose all its gas and go flat? Try this experiment to find out whether temperature affects the speed at which carbon dioxide gas escapes from soda pop.

Materials and Equipment:

Bottles of soda	Balloons
Plastic bowls	Ice
Water	String or ribbon
Metric ruler	

Procedure:

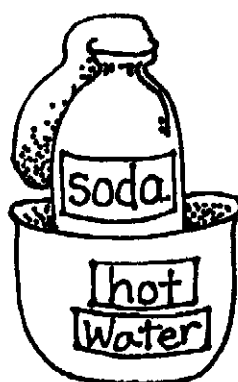
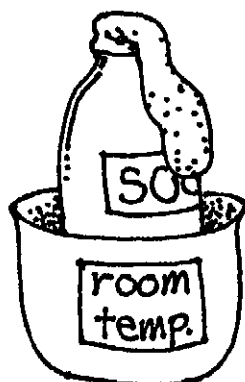
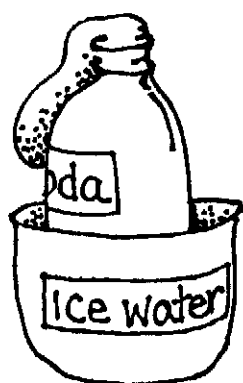
Have students predict whether warm soda will lose its carbon dioxide gas faster, slower, or at the same speed as cold soda. Open the three identical bottles of soda. Quickly cover each bottle with a balloon. Set the balloon covered bottles in the bowls of ice water, tepid water, and hot tap water. Wait five minutes. Wrap a string around

Bottle In:	Size of balloon after 5 minutes
Ice Water	_____cm.
Room Temp .	_____cm.
Hot Tap	_____cm.

the widest part of each balloon. Measure the length of the string with a metric ruler. Record the measurements in a data table. Compare the size of each balloon. Which temperature caused the carbon dioxide gas to have the fastest getaway from the soda?

Further Challenges:

- ☐ Which of these sodas would lose its gas (*go flat*) the quickest? (*An open soda in the refrigerator, a sealed soda on the counter, or an open soda left on a picnic table in the sun.*) Why?
- ☐ If you left the soda bottles covered for a longer period of time, would you collect more gas?
- ☐ Compare different brands of sodas. Do they all have the same amount of carbonation?
- ☐ Why is it not safe to put carbonated drinks inside a glass lined thermos?



Reference:

Adapted from Wonder Science, March, 1987 - American Chemical Society. Included in this Sourcebook by permission of the copyright holder.

Backdraft

by Mark R. Malone

Focus:

A backdraft situation in a building fire can be potentially very dangerous. A backdraft occurs when a fire is contained in an area where fresh air cannot enter. In this situation fire smolders and vaporizes combustible materials. Plastics often contribute greatly to this type of event. If air is suddenly allowed to enter into the room, much of the vaporized material combusts instantaneously. This entry of oxygen to fuel the explosion may occur in a number of ways. This could include: someone opening a door, fire burning through to the outside, firemen cutting a hole into a room with a fire ax, etc.

With this apparatus the backdraft occurs in a paper cup. First the match is placed in the center of the cup. It acts like a wick for the wax coating on the cup. The wax melts in a circular pattern. The paper of the cup chars. As this occurs the wax inside the cup begins to vaporize. *After the demonstration is over you will find that the vaporized wax has left a thin coating on the table.* A small hole is burnt in the top of the cup. After a moment the flame is drawn into the cup. This is followed by a small explosion. The cup may lift slightly off the table. In a darkened room a brief explosive flame may be seen. This is a miniature backdraft in a paper cup.

Challenge:

Observe the backdraft demonstration and describe the sequence of events that occurs. Attempt to explain why it occurs.

Material and Equipment:

Paper Cup	Smooth Surface
Matches	A draft free room

Procedure:

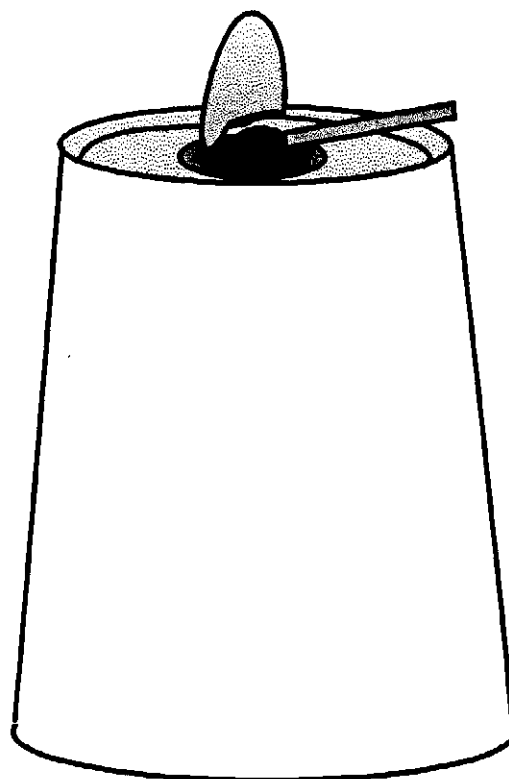
Invert a paper cup on a smooth surface. Be sure that there are no strong drafts present in the room. Place a lighted match on the top center of the cup as shown in the drawing. Observe the match and cup as it begins to burn. After a short time the cup will lift off the table with a dim flame and a puff of smoke. *With larger cups the effect can be quite dramatic.* Ask students to explain the sequence of events as they occurred. Ask them to try to explain what occurred and why. You may wish to repeat this activity

several times as students watch. You may wish to couple this demonstration with other combustion demonstrations.

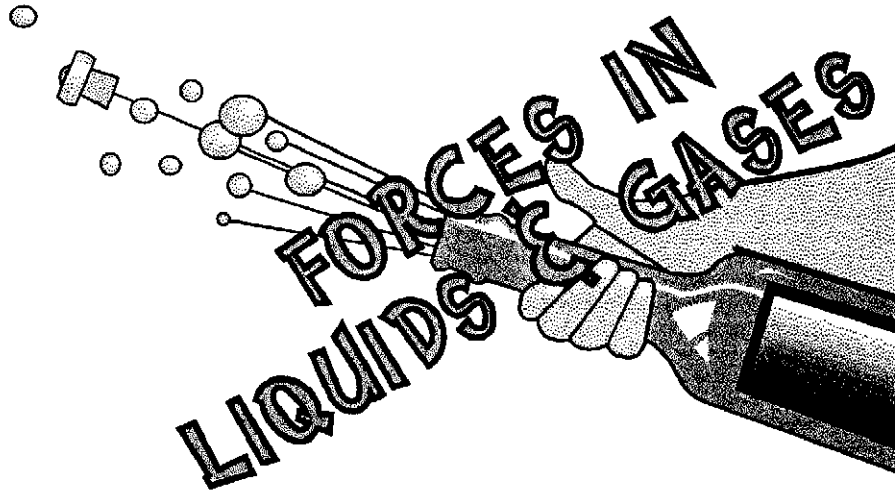
Safety: Because this activity involves the use of fire in a creative way, several precautions should be taken. A bucket of water and/or a fire extinguisher should be kept handy during the demonstration. This activity may not be appropriate as a "hands-on" group activity depending on the maturity level of students. Students should be cautioned against trying this activity at home unless supervised by an adult and unless appropriate safety precautions have been taken.

Further Challenges:

- ☐ Experiment with different sizes of cups. Is there an optimum size or type of cup that yields the best result?
- ☐ How does this activity pertain to fire safety in the home?
- ☐ If a fire breaks out in your home, why is it important to feel your bedroom door with your hand before opening it into a hallway?



CHAPTER - 9



Medicine Dropper Submarine

by Donna Gail Shaw

Focus:

In preparation for submergence, the main ballast tanks of a submarine are filled with water to decrease the vessel's positive buoyancy. One way to make the submarine float again is by using compressed air to force the water out of the tanks. The following experiment can be used to help illustrate this process.

Challenge:

How do submarines sink and then float again?

Materials and Equipment:

Soda bottle (2 liter)
Water

Medicine dropper
Paper towels

Procedure::

Gather enough materials prior to conducting the experiment. You should have one set of materials for demonstration purposes and one set of materials for each small group.

Begin the activity with a teacher demonstration and explain to the students that they will discover how it is possible for a submarine to sink and float again.

Students should carefully observe the following demonstration because they will perform the activity in their small groups. You may want the students to record the steps on paper. You may wish to refrain from discussing the demonstration at this time.

Demonstrate the following to your class. Fill a soda bottle full of water. Fill a medicine dropper with enough water so that it will barely float in the bottle of water. Place the cap on the bottle. Squeeze the bottle gently. The dropper should sink. Release pressure. The dropper should rise.

Make sure that all students know how to perform the activity. Pass out sets of materials to each group and have them repeat the experiment, record the results and record why they think the dropper sinks and floats.

After the groups have had a chance to perform the activity a few times allow students to discuss their explanation. Help students relate the activities results to the real world application of how submarines operate. Submarines take on water in order to sink and compressed air is used to force out water to make them float again.

The medicine dropper submarine works because of the ability to expand and contract air. When you apply pressure to the soda bottle with your hand, notice that water is pushed into the dropper. The air inside the dropper is forced upward into the dropper's bulb. With this extra water, the dropper becomes heavier and sinks. When you release the pressure, the air that was forced into the bulb of the medicine dropper expands and forces water out of the dropper. As a result, it becomes light enough to float again.

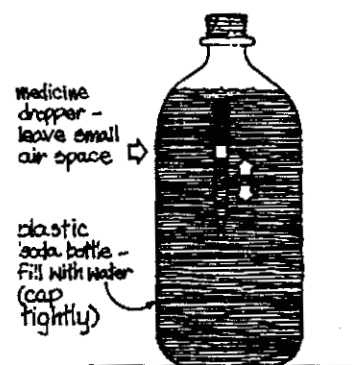
Further Challenges:

- ☐ Instead of using a plastic soda bottle, use a piece of rubber from a balloon and attach it to the top of a glass soda bottle with a rubber band. Press and release the rubber.
- ☐ Try to blow hard enough on the top of the glass or plastic bottle to make the dropper sink.
- ☐ Try this experiment with a plastic medicine dropper. Is it possible to fill the plastic dropper with enough water to make it heavy enough to sink? (Hint: If the plastic dropper will not sink, wrap a little copper wire around its base.)

References:

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Experiments for Everyone. New York: Doubleday Company.



Closed Systems

by Gerald Wm. Foster

Focus:

To observe the effects of various variables upon the density of liquids.

Challenge:

Students will attempt to make a floating test tube or some other objects sink.

Materials and Equipment:

Large test tubes	Small test tubes
Small vials	Rubber balloon
Rubber bands	Scissors
Newspapers or drop cloths	Wash tubs
A variety of plastic container	A variety of liquids

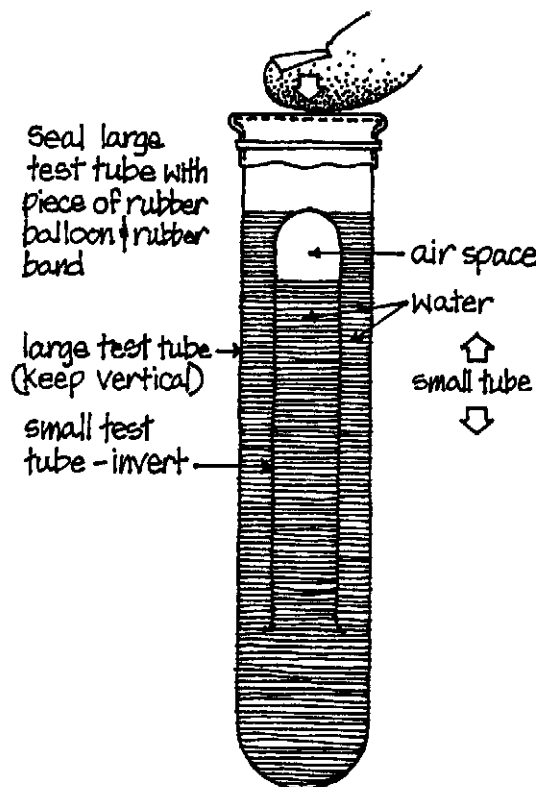
Procedure:

Fill a large test tube with water and invert a small test tube into large the test tube. The small test tube needs to have enough water in it to make the bottom of it float evenly with the water level of the large test tube. Stretch a piece of balloon over the opening of the large test tube and secure it with a rubber band as shown. Have one closed system made so that students can refer to it as they make their own. When the stretched balloon is depressed, the small test tube should sink to the bottom of the large test tube and remain there until released. Have students depress the stretched balloon with their thumb.

Once they have successfully operated the closed system, have students write down an explanation of how it works. They also need to identify the variables that affect the closed system. After that, they can start changing the variables. For example, students can use different liquids in the large test tube as well as the small test tube. Each time they use a different liquid, they should compare the level of the liquid in the small test tube to the level of water in the original closed system. Some suggested liquids might include: oil, vinegar, alcohol, salt water, glycerin, hydrogen peroxide, clear shampoo, etc.

Students can also try various plastic containers filled with various liquids using the small test tube as the diver. A lid

is put on the container rather than a stretched balloon. The sides are squeezed to make the test tube sink. Some suggested containers might include: plastic soda pop bottles, shampoo bottles, dishwashing liquid bottles, etc.



Further Challenges:

☐ Rather than using a plastic bottle or large test tube, use a narrow glass bottle such as a salad dressing bottle for the closed system. Make sure the water level is completely to the top of the glass bottle and screw on the cap as tightly as possible. The small test tube will sink when the glass bottle is squeezed if the amount of water in the small test tube is at the critical point of sinking or floating.

☐ Use a clear golf club spacer tube as a closed system. You will need a large rubber stopper in one end of the tube. Several small test tubes can be put in the large tube or even larger test tubes. Students can have test tube races to see which ones will reach the bottom first.

☐ Students can try water at different temperatures to see the effect on the rate at which the small test tubes will sink.

Heard It Through The Grapevine

by Edward L. Shaw, Jr.

Focus:

Carbon dioxide is a gas made up of one atom of carbon and two of oxygen. It is a gas with a variety of uses ranging from the powering of fire extinguishers to providing the fizz and bubbles in carbonated beverages.

An easy way to demonstrate CO_2 gas to students is to show how the bubbles rise to the top of the bottle when a carbonated beverage container is shaken and the top removed. Another method is to have students mix vinegar and baking soda in a container and show how the bubbles produced are carbon dioxide. An additional proof of the presence of CO_2 is that a lighted match will be extinguished if it is placed into the container.

Challenge:

Observation of carbon dioxide gas within a liquid.

Materials and Equipment:

Club Soda
Clear glass

Raisins

Procedure:

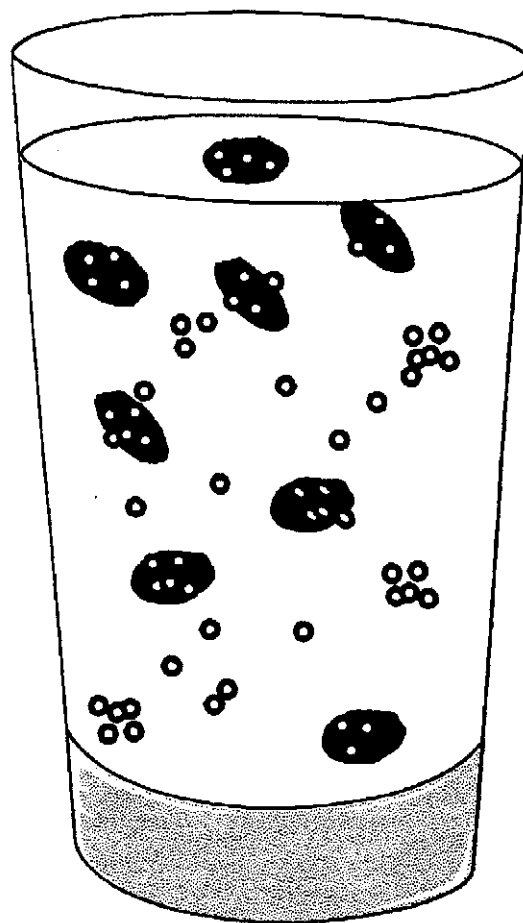
Ask students if they know how to make a raisin go up and down in a liquid without touching either the raisin or the liquid? Solicit answers and place them on the board. Distribute the raisins informing students not to disturb them because they have a lot of traveling ahead of them. Now distribute small glasses of the carbonated beverage, telling the students not to touch, smell, or taste it.

Tell them to carefully place the raisins in the liquid. Observe what happens. The CO_2 will accumulate on the raisins and they will rise to the top. Once the CO_2 bubbles pop, the raisins sink to the bottom only to repeat the process.

Ask students to describe the liquid and speculate about what it is. After they have guessed that it is a carbonated beverage, allow them to drink it and eat the raisins. Lead students through a discussion about what the bubbles are and why they rise and fall in the liquid.

Further Challenges:

- ☐ Have students determine if any characteristic of raisins (e.g., size, color, dryness, etc.) affect how well they travel.
- ☐ Have students determine if there are other fruits, vegetables, food or other items that will duplicate the process.
- ☐ Have students test to see if temperature of the beverage affects the movement of the raisins.
- ☐ Have students determine the length of time the raisins will float. Have them graph the number of round trips per five minutes.



Heaping High Water!

by Donna Gail Shaw

Focus:

Surface tension is caused by cohesion, a force that causes molecules of a substance to be attracted to one another. Surface tension causes a liquid to behave as if a thin, elastic film covers its surface. In actuality, no such film is present.

Challenge:

How many drops of water will it take to overflow a medicine cup "full" of water?

Materials and Equipment:

Medicine cups
Water

Medicine droppers
Paper towels

Procedure:

Ask the students how many drops of water they think it will take for the water to spill over the edges of the full cup. Demonstrate how to hold the medicine dropper an inch from the surface and explain that you will carefully drop one drop at a time. Have the students record their guesses on paper. Ask for volunteers to give you their guesses and record these on the board.

After you are sure the students know what to do, pass out the materials to each group. Each group should receive two medicine cups (*one full of water; the other half full to be used as a source of water for the experiment*), one medicine dropper and paper towels.

Students will use the medicine dropper to take water from the half full cup and carefully drop it into the full cup. One member of the group should be in charge of dropping the water into the cup, one should be in charge of counting the drops and one should watch for the point of overflow. Students should record the actual number of drops it took to overflow their cups of water and record why they think it took so many drops.

When all groups are finished, record the actual results on the board along with earlier guesses. Discuss the students' reasons why they think it took so many drops to overflow the cup. Why did it take one group more drops than

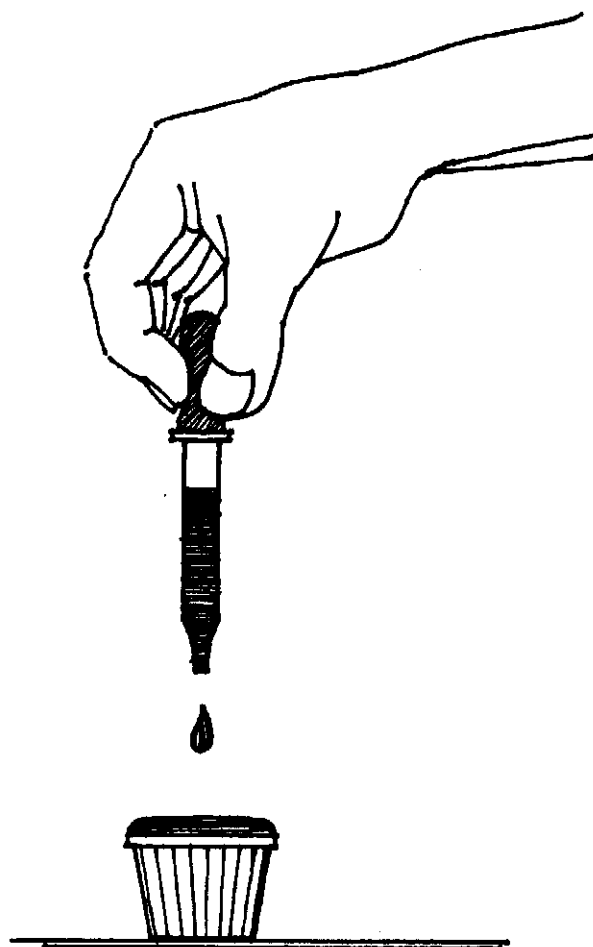
another? Discuss variables such as drop size, original amount of water in cup, height from which water was dropped, table or desk movement, air movement, etc.

Further Challenges:

- ☐ Will other liquids heap as high as water?
- ☐ Will soapy water heap as high as plain water? (*No, soap breaks down the cohesive force in water. This is why soap and detergent are used for cleaning.*)
- ☐ How many drops of water will a penny hold? Will the face or back of the penny hold more water?

Reference:

Kitchen Physics, Elementary Science Study.



Vanishing Ice Cube Trick

by Mildred Moseman

Focus:

The fact that ice floats is very important to us. Most liquids become heavier (*more dense*) as they turn into a solid. Because ice is less dense than water, it floats.

Challenge:

Floating ice traps the water of a pond underneath it, thus protecting the water from freezing. If ice sank, entire rivers and lakes could freeze solid from top to bottom. What would happen to fish in such a lake? How do bodies of water affect climate? How could the earth be affected if ice were heavier than water? Would climates change? How would people and wildlife be affected?

Materials and Equipment:

Glass
Ice cubes
Water

Procedure:

Fill a glass with water almost full. Add one large ice cube that will float freely in the glass as shown below. Now very carefully add more water. If you do it slowly, you can add enough water so the level rises above the top of the glass without spilling over. (*This is due to the surface tension. See the previous activity for more details.*) At this point, the ice cube will be floating above the top of the glass. Ask students to predict what will happen when the ice cube melts. (*As the ice cube melts, its volume decreases. Therefore the glass will not overflow.*)

Further Challenges:

☐ What happens when water is frozen in a paper or plastic cup? (*It expands and is therefore less dense.*)

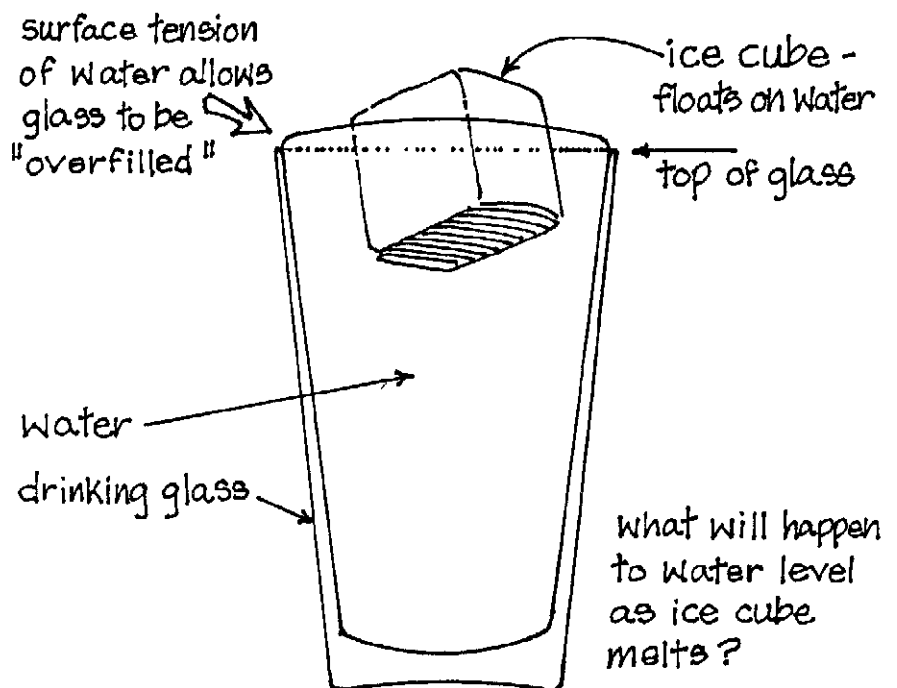
How does it illustrate the principle of the floating ice cube? (*Anything less dense than water will float on water.*)

☐ Ask students to speculate how life on earth would be different if ice sank when it froze.

☐ Observe solid shortening as it is melted over low heat. Does the solid (frozen) shortening float or sink to the bottom?

(*Note: Solid shortening will generally sink in warmer liquid shortening. Some solid shortening is whipped with air. It may be necessary to melt and re-freeze it before doing this demonstration with students.*)

Safety: Be sure to take adequate precautions when heating shortening to avoid burns or fire.



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Materials and Equipment:

Glass Water
Ice cubes

Procedure:

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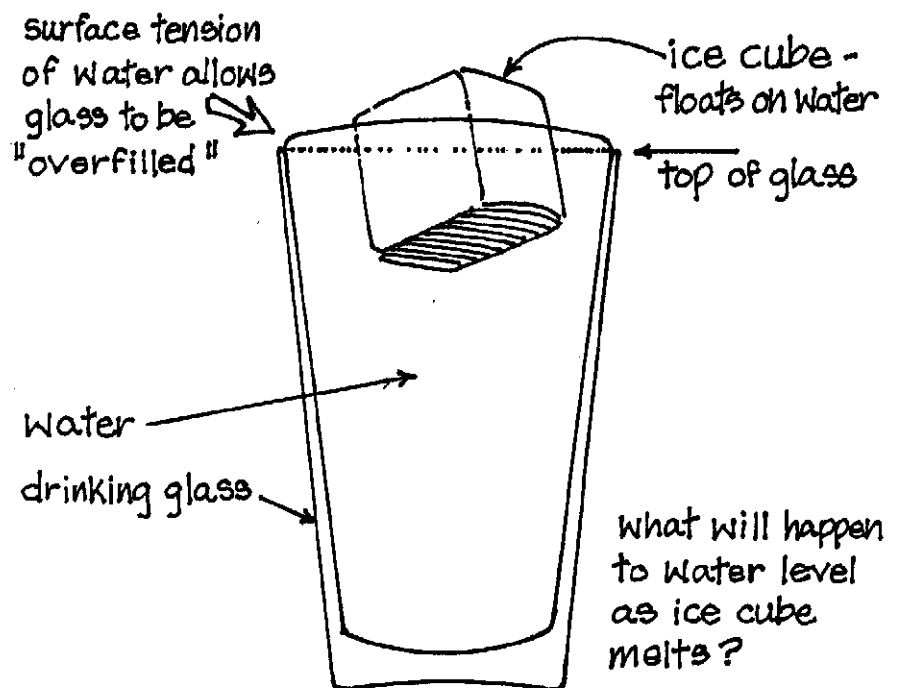
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Safety: Be sure to take adequate precautions when heating shortening to avoid burns or fire.



Soda Pop Sink Or Float?

by Gerald Wm. Foster

Focus:

Exploring the concept of density through observing that some unopened soda pop cans float while others sink when completely submerged in water.

Challenge:

Have students try to determine why some unopened soda pop cans will float in water while others will not.

Materials and Equipment:

An assortment of soda	Tubs
Newspaper	Paper towels
Drop cloths	Hot plates
Yeast	Plastic bags.
Scales	

Procedure:

Place a wide variety of types of soda pop cans in tub of water. Ten or more varieties would be helpful. Be sure to include both regular and diet sodas. Record which ones sink and which ones float.

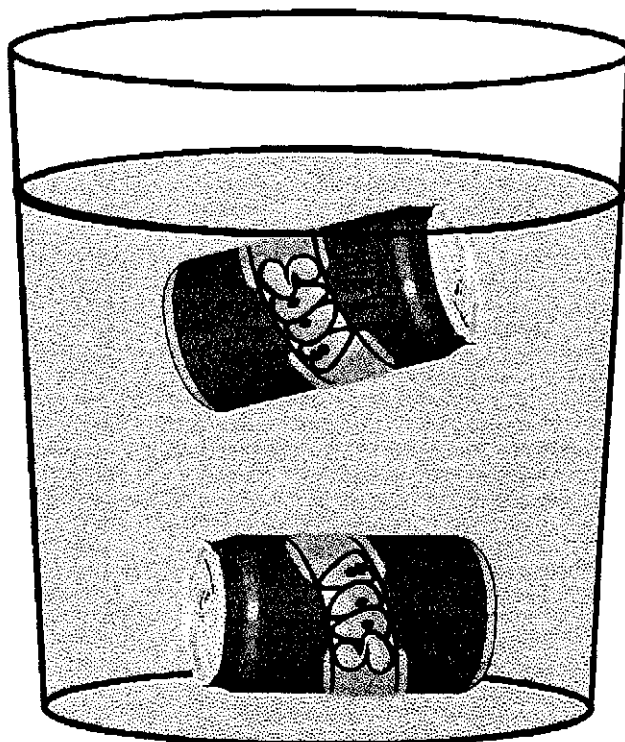
This activity allows students using a familiar material to do a fairly simplified scientific experiment of sorting and controlling variables. For example, they may want to try all of the colas first. They should also be aware of the volume and shape of each can and whether or not they are filled to the top. Students will have to check for air bubbles trapped underneath the cans to see if that might be the reason why they are floating. Students need to record their data to keep track of emerging patterns of those that sink and those that float.

Further Challenges:

- ☐ Check the contents of the can to see if that is making the difference in whether a soda pop can sinks or floats. How much of the content is water, sugar, carbonation, and other types of ingredients?
- ☐ Checking for sugar: put 50 ml of soda pop in a plastic lock top baggie with a package of dry yeast. Allow the

mixture to set for approximately 15 minutes in a warm (45°C) water bath. Students can approximate the amount of gas given off by how big the sealed bag becomes. The more gas given off the more sugar is in the mixture. Make one bag as control by placing one level spoonful (5 ml) of sugar and 50 ml of water. It would also be a good idea to allow the soda pop to stand to allow the contents to go "flat" prior to producing gas with the yeast. Otherwise, the carbon dioxide gas in the soda will become a confounding variable.

- ☐ Students may want to weigh each unopened can to see if there are differences in weight of the cans even though the volume may be the same.
- ☐ They may also want to heat the contents of the can to evaporate the liquid to see what kind of residue is left. This may also be affecting the ability of the can to sink or float.
- ☐ Students could also try floating the cans in other liquids such as salt water to see what happens.



The Mystery Of The Rising Water

by Donna Gail Shaw

Focus:

When the air inside the container is heated, the molecules of air speed up their movement and rush out of the container causing bubbles to form around the jar's mouth. The candle ceases to burn due to insufficient (not complete lack of) oxygen. As soon as the flame goes out, the air molecules in the container slow down their movement. This creates a low pressure area inside the jar. The relatively higher air pressure outside the container presses down on the surface of the water forcing it to go into the jar.

Challenge:

Make observations and inferences about reducing the air inside a container that is placed in water.

Materials and Equipment:

Wide mouthed jar	Pie tin
Matches	Candle
Water	Food coloring
Coin	

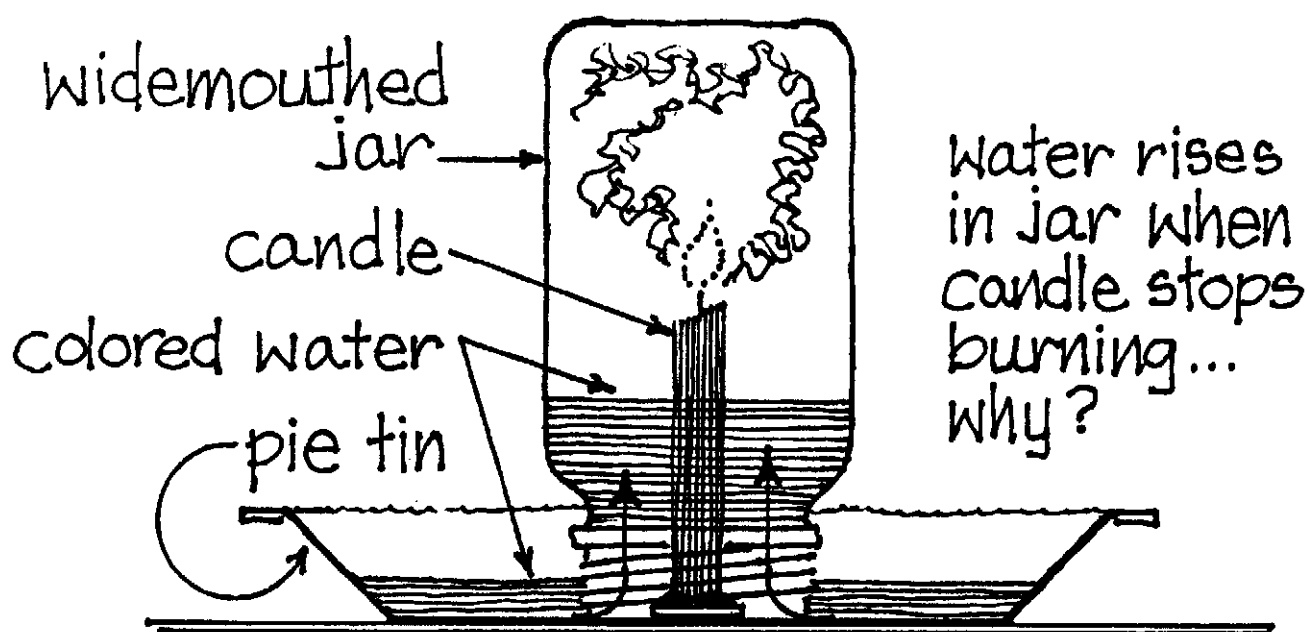
Procedure:

Prior to conducting the activity, students should understand that air takes up space, air is everywhere, and air exerts pressure. An adult helper would be a good safety precaution for this activity.

Gather enough materials prior to conducting the experiment. You should have one set of materials for demonstration purposes and one set of materials for every group.

Begin the activity with a teacher demonstration. Ask the students to watch each step carefully, because they will be asked to repeat the same steps in their groups. You may even want the students to record the steps on paper.

Fill a pie tin or similar container about half full of water. The activity may be somewhat easier to observe if you first color the water. Attach your candle to a coin by dripping hot wax from the candle on the surface of the coin. Insert the candle into the wax on the coin. Place the candle, with the coin attached, into the middle of the pan of water. Light the candle. Place the jar over the candle. Do this quickly so that all reactions can be observed. Ask students



to observe the results. You may wish to limit discussion at this point until students have a chance to repeat the activity.

Make sure that all students know how to perform the experiment. Pass out sets of materials to each group and have them repeat the experiment, record the results and record inferences about what they think happened.

After the groups have had a chance to perform the experiment a few times, you may wish to summarize the students' observations on the board.

Some expected observations include:

- a. Bubbles appeared around the mouth of the jar when it was placed over the candle.
- b. Candle stops burning.
- c. Water rises in jar.
- d. Water rises about one-fifth of jar's height.

Next, write student inferences about the results on the board. Some expected inferences include:

- a. The bubbles are caused by hot air rushing out of the jar.
- b. The candle went out because of lack of oxygen.

- c. Since air is about one-fifth oxygen and the water rises about one-fifth the height of the jar students oxygen was occupying. (Please note that this inference is incorrect, see the *Don't Suffocate That Mouse* activity.)
- d. The water replaced the space the air was occupying before it rushed out of the jar.

Discuss observations and inferences as they are recorded on the board.

Further Challenges:

- ☐ Use clear plastic containers in place of jars. Put a hole in one or two of the groups' clear plastic containers. One of two things will happen; the water will not rise in the container or it will rise and then quickly fall again. This is because air is allowed back in the container.
- ☐ Experiment with larger or smaller candles. Will this affect the results?
- ☐ Experiment with different container sizes. Will this affect the results?

Reference:

Nelson, L. W. (1984) *Science Activities for Elementary Children*. Wm. C. Brown Publishers, Iowa.

Don't Suffocate That Mouse!

Donna Gail Shaw

Focus:

The manipulation of the flow of air or the amount of air inside or outside a container can cause the interesting results as seen in "The Mystery of the Rising Water" activity. However, sometimes just doing one experiment can cause one to develop incorrect hypotheses. This could easily happen in the previously mentioned experiment.

Though a candle ceases to burn in an enclosed container, all of the oxygen is not burned up. There is simply not enough oxygen remaining to support a candle flame. Because not all the oxygen is consumed, the mouse remains alive and active. Mammals like mice require a significantly lower proportion of oxygen in the air than is required to support a candle flame.

Challenge:

Will a mouse suffocate if placed inside an enclosed jar with a burning candle?

Materials & Equipment:

White mouse	Candle with holder
Matches	Glass container with lid

Procedure:

This activity is a teacher demonstration. It is highly recommended that the activity entitled "The Mystery of the Rising Water" be conducted prior to this lesson. Refer back to the rising water activity. Review the observation and inferences. Particularly focus on the fact that the candle ceases to burn and why. If the students have concluded that all the oxygen is burned up, don't correct them. Tell them the purpose of this activity is to determine if the candle's flame did burn off all the oxygen in the container. You may want the students to record their observations and inferences as you demonstrate.

Place the mouse in the jar. Put the candle in the jar. Light the candle. Be sure that the candle is tall enough that the mouse cannot touch the flame. Put the lid on the jar. Students should carefully observe what occurs inside the jar.

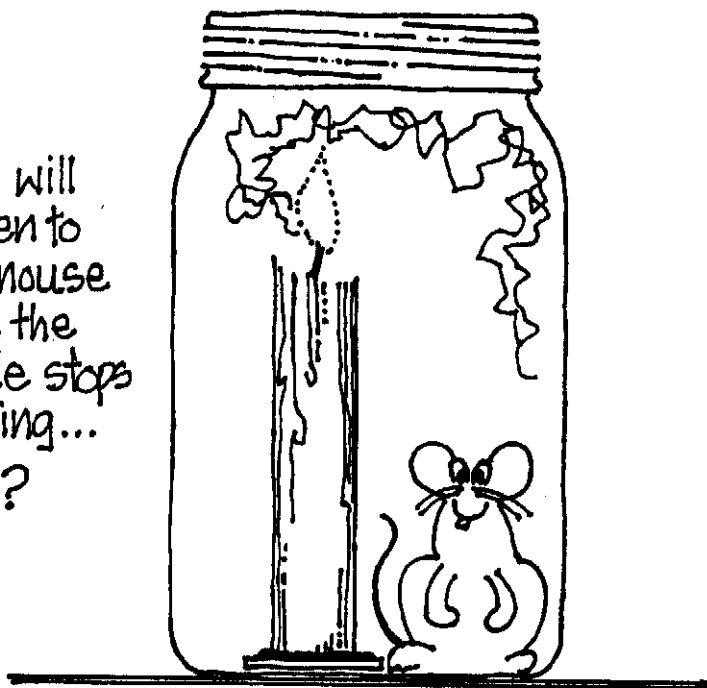
They will quickly see that the candle goes out but the mouse remains alive and active. After students are sure that the mouse is breathing normally, remove the mouse from the jar. A lively discussion should follow.

Further Challenge:

☐ This activity could be related to how candles were used on early submarines. Candles were used as a safety device to sense when oxygen was getting low. When the candle went out, it was time to surface and take in some fresh air.

☐ Students may wish to do some library research on early submarines.

What will happen to the mouse when the candle stops burning... why?



Making Your Own Bernoulli Blower

Mark and Meghan Twiest

Focus:

Investigate the principle that gives airplanes their lift.

Challenge:

Suspend a ball in the air through the application of Bernoulli's Law.

Materials and Equipment:

Shop vacuum (capable of blowing air through its hose)
Plastic ball (3-6 in. diameter)

Procedure:

This simple demonstration illustrates a very important concept. Bernoulli's Law states that fast moving air creates low pressure. You can verify this fact by conducting this simple and interesting investigation.

To begin, attach the hose to the vacuum cleaner so that the air blows out of the hose rather than being sucked in as it usually does. When you first turn the vacuum on after doing this, be sure to point the nozzle of the hose towards the ground. This will prevent any objects in the hose from striking you or your students. Once the hose is free of any loose particles, point the nozzle straight up.

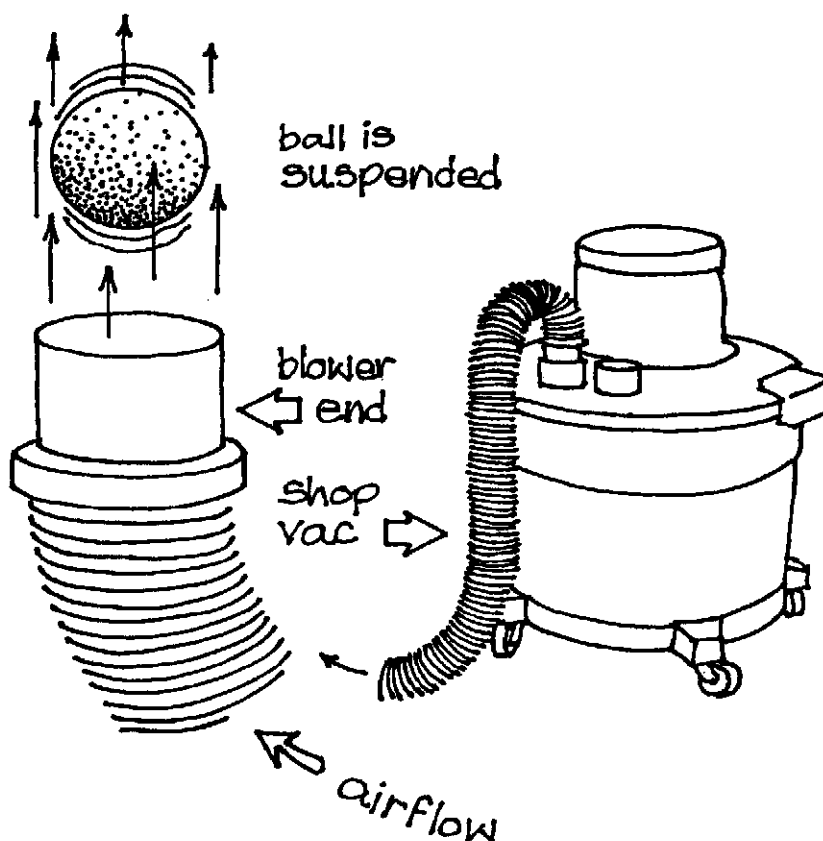
You now have a column of air moving vertically at high speed. Take the plastic ball and place it in this column of air. You may find that if you place the ball too low in the column it will shoot up and out of the column. Conversely, if you place the ball too high in the air stream, it will fall out of the stream's grip. In only a few tries, you and your students should be able to place the ball so that it will remain suspended in midair after you release it.

Now that you have successfully floated the ball, ask one of your students to very

gently pull the ball perpendicularly out of the air stream. You should be able to feel the ball resisting your efforts to move it. This is because when the ball is half in and half out of the column of air, the fast moving air on one side of the ball creates low pressure. The resulting higher pressure on the other side of the ball tends to force the ball back into the column of air.

Further Challenges:

- ☐ Can you make the ball float when the column of air is not vertical?
- ☐ Can you design another shape that will float in the air stream?
- ☐ How does this principle relate to the shape of an air foil?
- ☐ This activity can also be done on a larger scale using a box fan. The fan will need to be propped up so that it blows up and has sufficient air space under it. Challenge students to float a beach ball over it.



Jet Engines

by David R. Stronck

Focus:

Children know that airplanes and space vehicles have jet engines. But they may not know why such engines can cause motion. This activity will help the children to understand the process that begins with a chemical reaction. This chemical reaction generates a gas that is released through a small opening. The action of the gas moving out through this opening generates an equal but opposite reaction. The airplane or other vehicle moves forward because of this reaction.

Challenge:

Can you build your own jet engine and make it do work?

Materials and Equipment:

Dish soap container
Baking soda
Plastic spoons
Facial tissue

Vinegar
Paper cups
Water
Twist tie

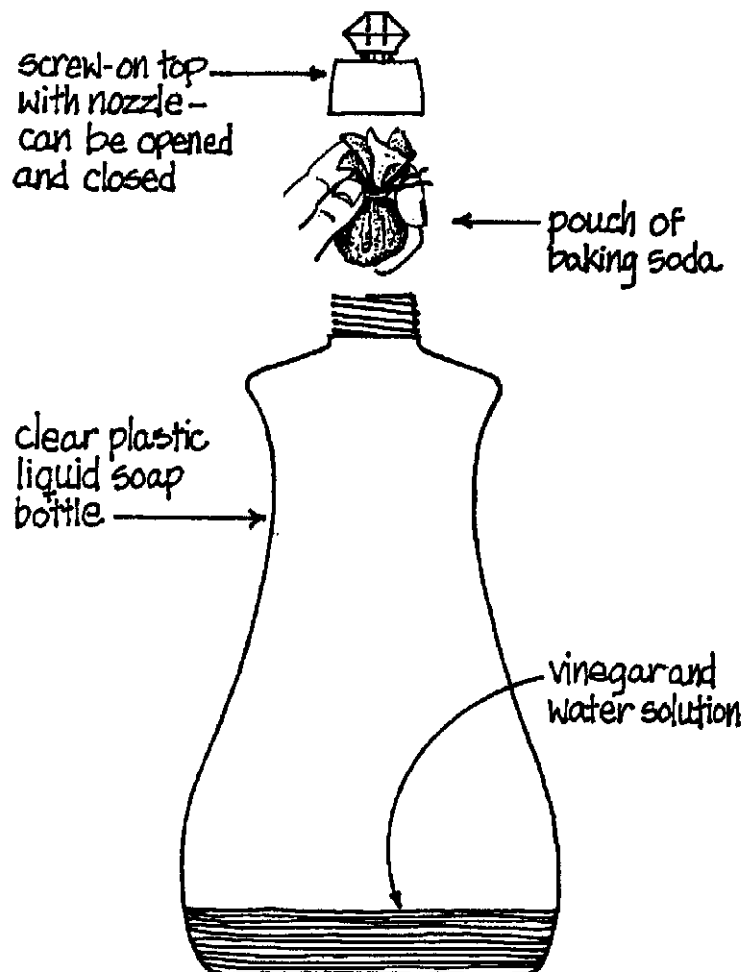
Procedure:

Ask the children to explain what they know about jet engines. Ask them if they know how they work. Invite the children to make and test their own jet engines like the ones pictured in this activity

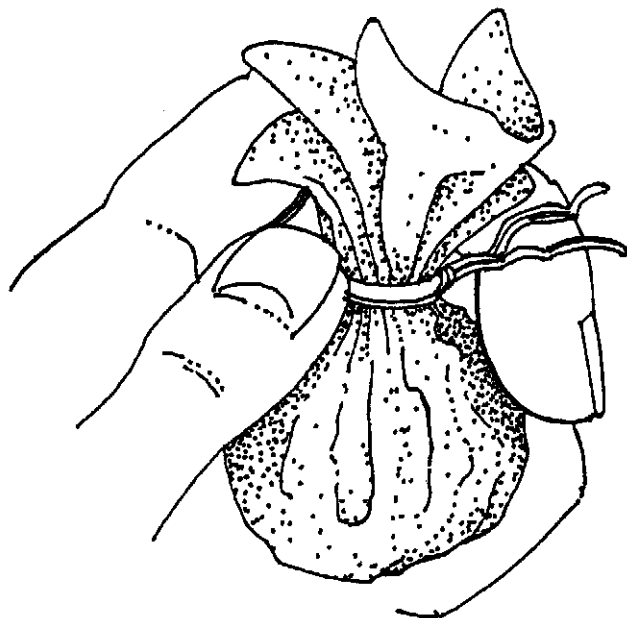
Provide each pair or team of students with an empty dish soap container. Each container should have a small nozzle opening that can be opened and closed. Have the children remove the cap of this bottle and add in a couple of tablespoons of vinegar and several tablespoons of water. Next, they will place a teaspoon of baking soda onto a facial tissue. They will then fold up the edges of the tissue and tie them together with a twist tie. This forms a small pouch. Excess tissue above the twist tie should be cut off and discarded.

The rest of the activity is best done outdoors or in a large open space. Tell the children to carefully place the tissue pouch into the container. Instruct them to be careful that the baking soda pouch does not come into contact with the vinegar solution. Make sure the nozzle on the cap is closed and place the cap tightly on the container. Now have them place their thumbs firmly over the nozzle to assure that the pressure does not open the nozzle prematurely. Shake the container briefly to mix the vinegar with the baking soda in the pouch. Finally place the container on its side on the sidewalk or pavement and open the nozzle. Record the behavior of the container.

Discuss with the children what happened. Help them to explain how the chemical reaction generated a gas. This gas is carbon dioxide. The same gas is generated in our stomach if we ate baking soda and drank vinegar. The



same gas is in soda pop. The gas causes motion because it can escape through only one place. This gives the container motion in the opposite direction.

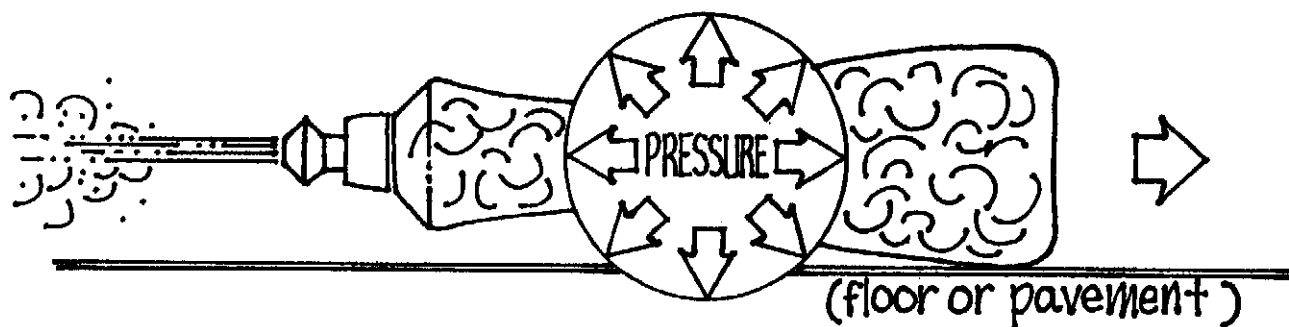


Safety: Be sure that the surface where this investigation is conducted will not be damaged by the vinegar and baking soda solution. Safeguards should also be taken to assure that students are not accidentally sprayed with the jet of solution. While it is unlikely that the containers will burst, it is possible. Safety goggles should be worn during appropriate parts of this activity.

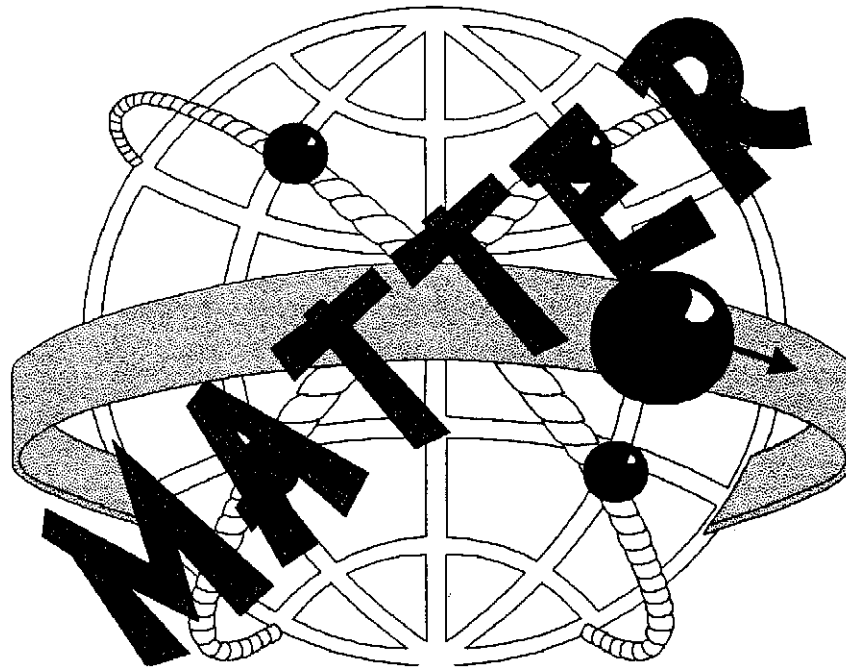
Further Challenges:

☐ Invite the children to make such improvements on the container that it will move in one consistent direction. For example, if the container had wheels it could move as if it were a jet propelled automobile. If the container was suspended by a couple of paper clips to a long wire strung tightly and horizontally, the container could seem to move through air like an airplane. The children may suggest wings, tails, etc.

☐ Ask the children to improve the chemical reaction. Should they add more or less of the baking soda, water, and/or vinegar? What mixture gives the best results?



CHAPTER - 10



Particle Free For All

by Edward L. Shaw, Jr.

Focus:

The "Brownian Movement" is the irregular motion or movement of an organic or inorganic body, arising from the thermal motion of the molecules of the material in which the body is immersed. The body will have many collisions with the molecules, which results in the imparting of energy and momentum to it. Because there will be fluctuations in the magnitude and direction of the average momentum transferred, the motion of the body will appear irregular and erratic. (*This concept was discovered by Robert Brown, a Scottish botanist, in 1858.*)

Challenge:

Observation of the "Brownian Movement."

Materials and Equipment:

Dark classroom	Projector
Chalk erasers	Beaker
Nonfat dried milk	Water
Stirring rod	

Procedure:

There are two ways to perform this experiment; both are easy and inexpensive. The first and simplest way begins with darkening the classroom. Have a filmstrip or slide projector directed toward the front of the room with the lamp switch on. Have students sit very quietly so that the movement of air is minimal. Clap the two erasers together to release the chalk particles. Ask students what they see. What are the chalk particles doing? Are there certain patterns formed by the chalk particles?

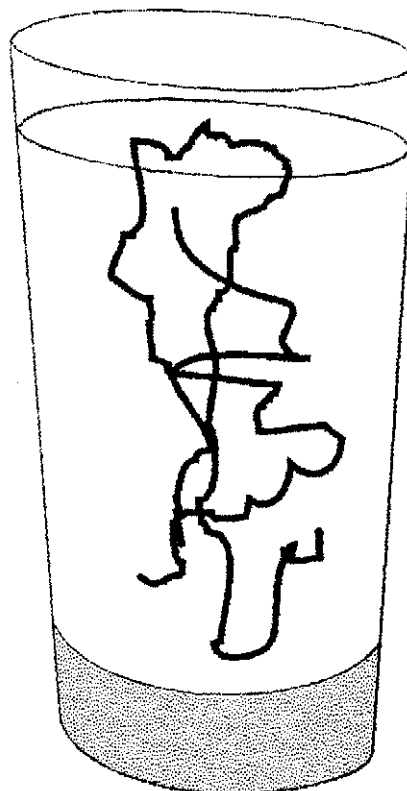
Now the second or follow-up activity should begin by having a beaker of water already prepared. Have students predict what will happen when the powdered milk is added to the water. Stir the solution enough so that it becomes opaque. Stop stirring and have students observe what happens. Are there any patterns? What are the particles doing?

After the two demonstrations have been completed, discuss with students their observations. Introduce the concept

"Brownian Movement or Motion." The particles from the chalk and powdered milk represented bodies coming in contact with molecules (air and water.) The result of the collisions was an increase in the momentum and energy of the bodies. Since momentum and energy were not consistent, the motion of the bodies appeared irregular and erratic.

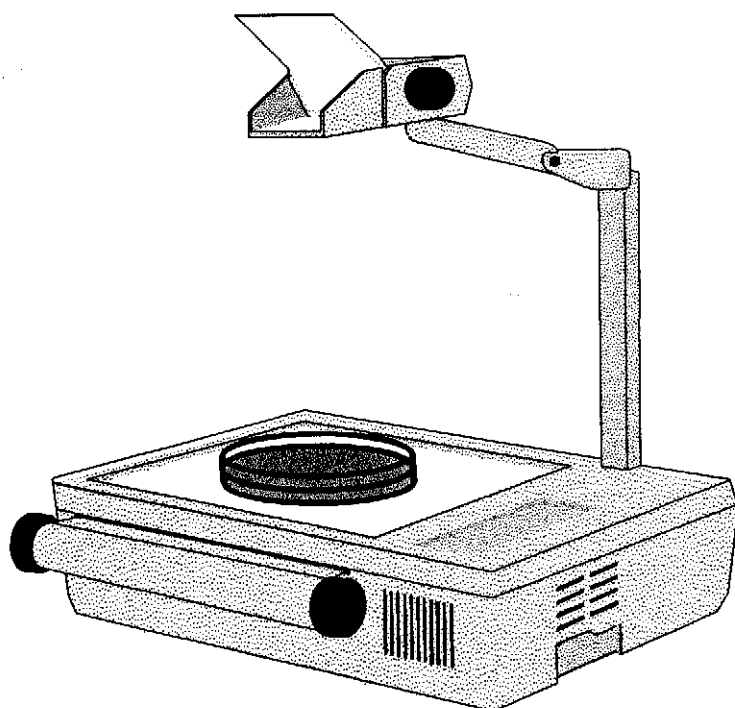
Further Challenges:

- ☐ Have students determine if there are other media which can be used to demonstrate this concept such as a gas or a less viscous liquid (*e.g., oil and vinegar dressing.*)
- ☐ Ask if students believe that a temperature increase or decrease will affect the motion of the bodies.
- ☐ Ask students to make observations of food coloring dropped into water. This is particularly interesting when observing differences between hot and cold water.



From Here To There

by Patsy Ann Giese



Powdered dye or drink mix

Large clear container

Potassium permanganate (*crystal or powder*)

Phenolphthalein solution (*0.5 g. phenolphthalein crystals in 100 mm of rubbing alcohol*)

Procedure:

Place a petri dish or other clear flat-bottomed container on an overhead transparency projector. Add lukewarm water to the dish. When the water is still, add a crystal or a little powdered potassium permanganate (KMnO_4) to the water. Have students draw pictures of what they see.

Repeat the above activity simultaneously using a petri dish of cold water and a petri dish of hot water. The demonstration is more graphic the greater the difference in temperature between the two dishes of water. Be sure the same amount of potassium permanganate is put into both petri dishes. Students should infer that particles move faster when heated.

Focus:

Particles of matter (*atoms and molecules*) are in constant motion. The temperature of a quantity of matter is a measure of the average rate of motion of the particles. The particles in a solid, usually bound into a crystalline structure, vibrate within a limited space. Distances traveled by particles in a liquid are greater, and in a gas are the greatest. Some gas molecules reach speeds of more than 1000 miles per hour.

Challenge:

Observe evidence and infer that particles of matter are constantly moving.

Materials and Equipment:

Overhead projector
Measuring spoon
Cotton
Masking tape
Onion
Cutting board
Cellophane

Petri dishes
Water
Wooden dowel
Household ammonia
Knife
Perfume
Food coloring or ink

Tape cotton to a dowel to form a large cotton swab. Soak the cotton in a solution of phenolphthalein, which should be clear. Then hold the cotton above an open bottle of household ammonia. The cotton will turn pink, showing particles of ammonia are escaping from the bottle.

Further Challenges:

☐ At the back of the room, slice an onion or pour perfume out of a bottle. Have students raise their hands (*without looking behind them*) when they can smell the onion or perfume. Have students in the back row describe the order in which students raised their hands.

☐ Drop food coloring or ink into a large clear container of still water. Have students draw pictures of what they see.

☐ Pour a package of powdered dye or drink mix into a large clear container of still water. Have students observe at regular intervals, and see how long it takes for the powder to dissolve without any stirring.

☐ Discuss why brightly colored clothes should be washed in cold water. Discuss why strong coffee or tea must be made with hot water.

☐ Discuss why cookie or bread dough has a stronger odor when cooking than when waiting to be cooked. Discuss why barnyards have a stronger odor during summer than during the other seasons.

☐ Discuss whether clothes on a line would ever dry if particles of water did not constantly move. Discuss whether clouds would form in the sky under that same condition.

☐ Discuss what happens to the molecules in a mothball as the mothball disappears.

Safety: Do not let any children sniff the ammonia close to the bottle. Ammonia fumes, if concentrated, can irritate one's eyes and nose. As with all chemicals, follow label directions and precautions.

Chemical Detectives

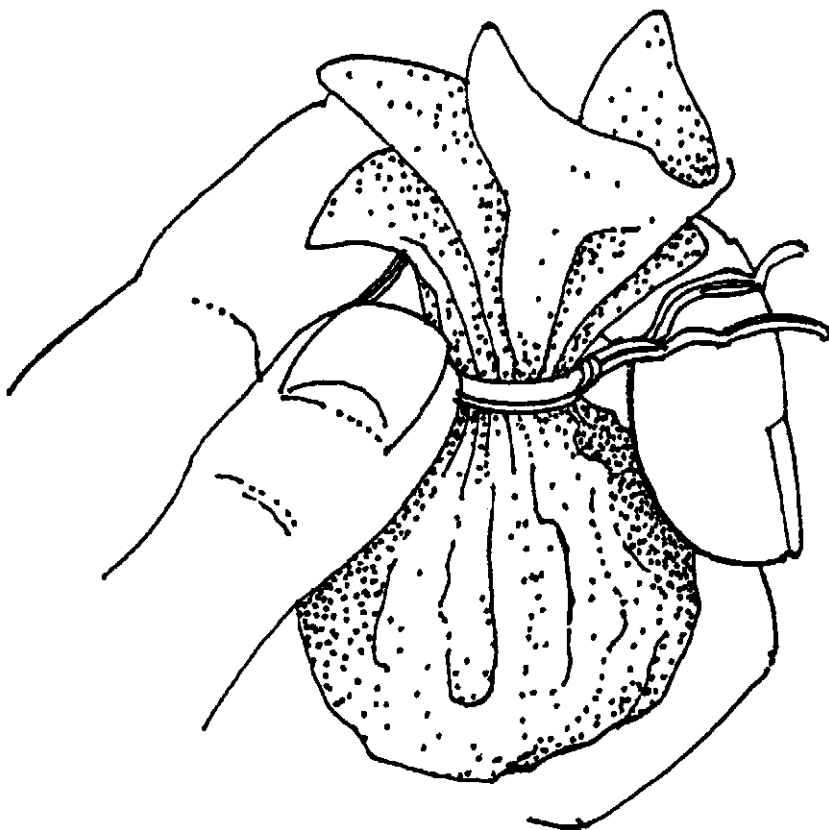
by Terri G. Switzer

Focus:

All chemicals are built from small particles. These particles, such as atoms, molecules, ions, and electrons, are too small for students to see or feel directly. But, by experimenting with common food chemicals from the kitchen students can use indirect evidence to detect that substances contain smaller particles.

Challenge:

If you add a teaspoon of Koolaid, or sugar, or salt to a glass of water and stir with a spoon, the food chemical dissolves (*mixes with the water*). But what would happen if you wrapped a teaspoon of the same material inside a paper towel sack before you put it in the water? Do you think the food will be able to get out of the bag and mix with the water?



Materials and Equipment:

Powdered drink mix	Teaspoons
Sugar	Salt
Pencils	Paper towels
Clear plastic glasses	Twist ties
Water	Newspaper
Hand lenses	String

Procedure:

Point out that while powdered drink mix (e.g., Koolaid), sugar, and salt are food chemicals we commonly use at home, students should never test or taste any food chemicals unless a teacher or parent says it is safe to do so. There are many household materials that may seem safe, but aren't, especially when mixed together or used improperly.

Supervise this activity closely to ensure that students use only clean glasses and spoons, freshly opened Koolaid,

sugar, and salt, and that they wash their hands. If these precautions are taken, you can give students permission to take one small taste of these foods when directed. (*They are not to eat the foods, only taste!*) Your students can obtain valuable sensory information from tasting during this activity, but it is not mandatory to taste anything to be a chemical detective!

Conserve supplies by having students work in teams of three with each team member responsible for testing one of the foods.

Look closely at the dry Koolaid, sugar, and salt with a hand lens. Have students compare the shapes, sizes, colors, and smells they observe.

Place a teaspoon of Koolaid in the center of one of the paper towel squares. Tie the corners of the towel firmly together with a twist tie to make a sack as shown. Hang this sack from a pencil by the twist tie. Make another sack for sugar and one for salt.

Gently shake and squeeze each sack. Can the students get the food to come out of the sacks without breaking or tearing the bags? Students should notice that the food pieces are too big to pass through the tiny pores in the towel. If they don't see the pores, have them look closer with a hand lens, or hold the towel up to the light.

Have students predict what they think will happen if they soak the sacks in water. Have them think about how the different sizes and shapes of the food pieces may affect what happens.

Students can test their predictions by laying the pencil across a glass of water so the sack hangs down into the water. Watch closely, and have students describe what happens. They should see a "river" or "water fall" of the food leaking through the bag and into the water. Is this what they predicted? Watch for several minutes.

Lift each sack out of the water and lay it on a tray or newspaper. Open the bags and look closely at what is left inside. Compare the wet foods to the dry foods they observed in step one. Students should notice that water leaked into the bag and the pieces have changed shape, size, and color. They may notice that there is less food in the bag now. Where did the food go and how did it get out of the bag?

Students can detect the salt, sugar, or Koolaid in the glasses of water by dipping their clean finger into the glass and tasting a tiny amount. Ask them to explain why the dry food couldn't get out of the bag but the wet food could. They should discover that water leaked into the bag and helped tiny food particles leak out through the holes in the paper.

Further Challenges:

☐ Let students make more sacks and test other foods that you approve. (e.g., brown sugar, flour, cornstarch, coffee, tea, baking soda) Which foods leak particles in the same way as Koolaid, sugar, and salt? Let students try to figure out why some foods won't leak through in the same way. Maybe the particles are still too big to get through the towel!

☐ After soaking the sacks, pour the water from the glasses into shiny metal pie pans or cookie trays. Label the pans so students remember what was in each one. Set the pans in a sunny place for a few days to let the water evaporate. Use a hand lens to see if the tiny particles left behind on the bottoms and sides of the pan are similar to the foods you started with. When the water evaporates, the tiny food particles that were mixed with the water are left behind.

☐ What would happen if you let a pan of plain tap water evaporate? Would there be any particles left behind then?

☐ What would happen if you let a pan of distilled water evaporate? Would there be any particles left behind then?

Reference:

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The Whole Is Less than the Sum of the Parts

by Patsy Ann Giese

Focus:

All matter is made of very small particles (*atoms or molecules*). The space between the particles is greater than the space occupied by the particles themselves. A smaller particle can occupy the space between larger particles. Therefore, the sum of the volumes of two separate substances is greater than the volume formed when the two are mixed.

The fraction of the total volume of a solid that is occupied by particles varies with the crystalline structure of the solid. In any liquid, about $\frac{1}{3}$ of the total is space occupied by the particles. Changes in temperature or pressure do not change this fraction much. In any gas at normal temperature and pressure, about $\frac{1}{2500}$ of the total is space occupied by particles. This fraction changes considerably with changes in temperature or pressure.

Challenge:

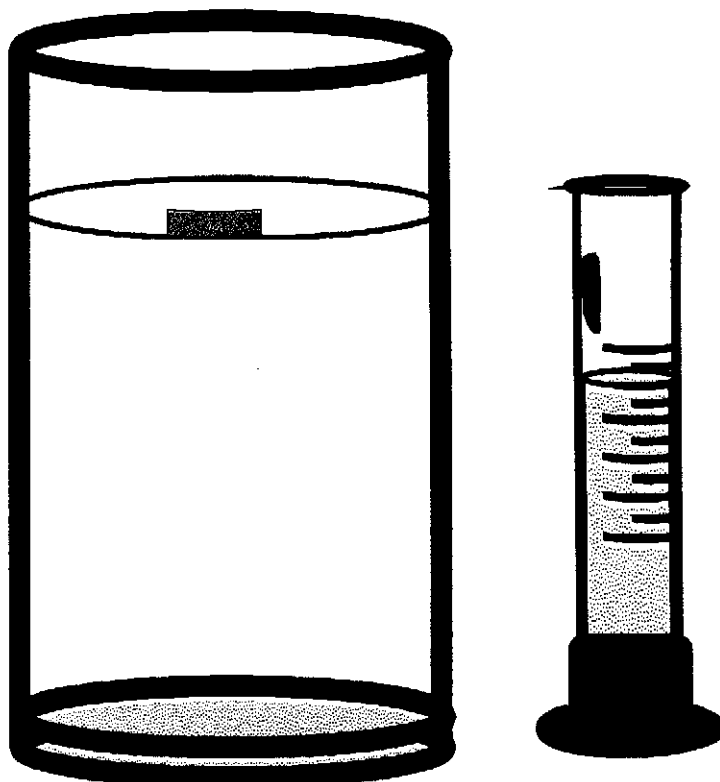
Observe evidence and infer that particles of matter are separated by spaces.

Materials and Equipment:

Clear jar or pitcher	Water
graduated cylinder (200 ml.)	Sugar
Powdered drink mix (<i>unsweetened</i>)	Spoon
Paper cups	Beakers (500 ml.)
Small beads or BB shot	Large beads or marbles
Glass tube about (apx. 10 x 100 cm.)	Corks
Rubbing alcohol	Food coloring
Masking tape	

Procedure:

Fill a jar or pitcher with about 1500 ml of water. Stick a piece of masking tape to the bottom of the container to mark the water level. Likewise mark the height of about 150 ml of sugar in a container. For best results, use a container with a small diameter, such as a graduated cylinder. Pour the sugar into the water, and mix with a



spoon until the sugar is dissolved. Then pour enough sugar water back into the sugar container so that the level in the water container is the same as before adding sugar. Have students notice that the height of sugar water in the sugar container is less than the original height of the sugar. Water molecules are smaller than sugar molecules so water molecules fit into the spaces between sugar molecules. You may wish to add a package of powdered drink mix so students can enjoy consuming the experimental evidence.

Put a cork into the bottom opening of a glass tube. Pour colored water into the tube until it is almost half full. Gently pour rubbing alcohol over the water, making sure the two liquids mix as little as possible. When the tube is nearly full, seal the top of the tube with a cork. Mark the height of the liquids with a piece of masking tape wrapped around the tube with the bottom of the tape at the top of the alcohol. Then alternate inverting the tubing and checking the height of the liquids. As the liquids mix, the height of the liquids will decrease. Ask students if you could get rid of all the liquid this way. Then show that the height stabilizes when the liquids are thoroughly mixed. (*If you do not invert the tube, the liquids will not mix for months. Convection currents based on the different densities of*

water and alcohol do not develop because the tube is too narrow.)

Further Challenges

□ Have students check if they can taste the sugar in the water even though the sugar particles disappeared (*got too small to see*) as they dissolved. You can sample various parts of the container by putting a straw in the liquid, covering the top with your finger, and lifting the straw and a little liquid out of the container. Pour sugar water through a coffee filter, and then have students taste it. Have students infer that sugar passes through the filter because sugar molecules are smaller than the openings in a coffee filter. Boil or evaporate the water from the sugar water obtaining sugar as the residue.

□ Repeat the procedures described above, except pour clear water over colored water in a tube. Because the molecules of water are all the same size, mixing will not result in loss of volume. Repeat again, except pour clear alcohol over colored alcohol.

□ Repeat the procedures described above, except pour alcohol into a tube before colored water. The two liquids mix immediately because water molecules are more dense than alcohol molecules. The density of alcohol (*about 0.8 grams per cubic cm*) is less than the density of water (*about 1.0 gram per cubic cm*).

□ Put 200 ml of small beads or BB shot in a 500 ml beaker and 200 ml of large beads or marbles in another 500 ml beaker. Pour the small objects over the larger ones. Have students notice that the total volume is less than 400 ml because the small objects fit into spaces between the large objects. Repeat, pouring the large objects over the small ones. Have students describe the difference in total volume compared to the previous demonstration. Then mix together the large and small objects, checking the total volume. These objects form a model for the particles that are too small to see in the sugar, water, and rubbing alcohol. (*An alternate model is clean sand used with small beads or BB shot.*)

□ Fill a narrow necked flask about 1/3 full of water softener salt pellets. Then add warm water till the water level is in the upper part of the narrow neck, and mark the water level with tape as described above. Measure the water level every five minutes for an hour. Also, observe the size of the salt pellets.

□ Have students find the volume of a glass marble using the formula for a sphere ($\frac{4}{3}$ times pi times the cube of the radius.) Then fill a graduated cylinder about half full of water. The inside diameter of the graduated cylinder must be larger than the diameter of the marble. Read the water level, add the marble to the water, and read the water level again. Repeat these procedures, except use a steel marble the same size as the glass marble. The sum of the volumes of a marble and water separately is the same as the volume formed when the marble is added to the water. Unlike two liquids, the marble and water cannot be mixed together with the water molecules fitting in between the marble molecules. Although the steel marble is heavier, it does not raise the level of the water any more than the glass marble does.

Safety: Remind students to never taste an unknown substance. They can taste the sugar water only because you have told them it is safe. If you place marbles in a glass graduated cylinder, tilt the cylinder as you roll the marbles in along the side of the cylinder. Otherwise, they will drop too fast and break the bottom of the cylinder.



50 Plus 50 Doesn't Always Equal 100

by Donna Gail Shaw

Focus:

Molecules are so small that they cannot be seen with a regular classroom microscope. It is difficult for children, and even adults, to conceptualize that there are spaces between molecules of a substance since the space is not visible to the naked eye. The following activity illustrates that liquids have space between their molecules.

Challenge:

Fifty ml of duplicating fluid and 50 ml of plain water will not make 100 ml of liquid when mixed. Where does the missing liquid go?

Materials and Equipment:

Olive jars or graduated cylinder
Duplicating fluid or alcohol

Water

Procedure:

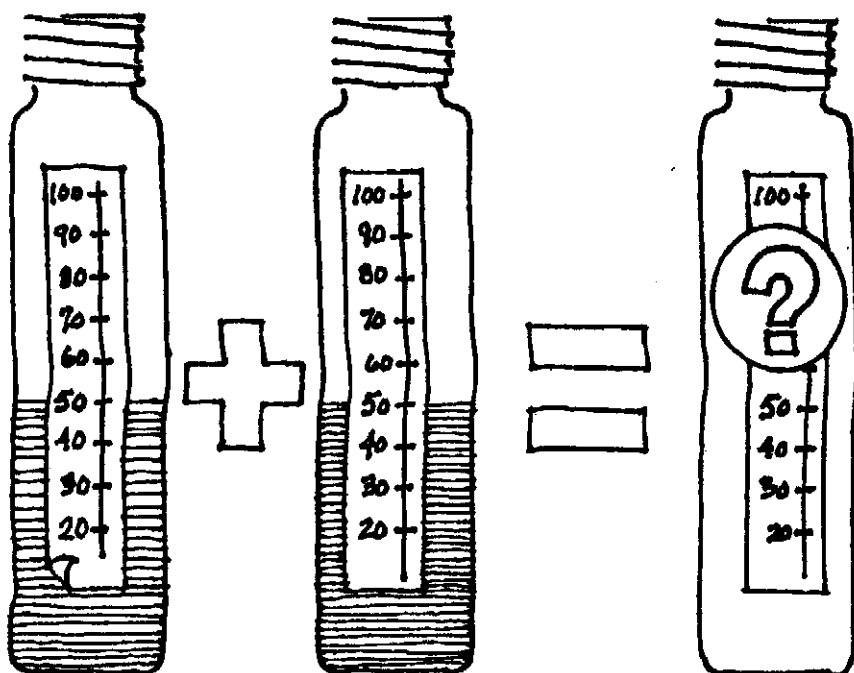
This activity can be conducted as a teacher demonstration or in small groups. Safety precautions for using dangerous liquids apply.

Begin by pouring 50 ml of water into one olive jar or graduated cylinder. Pour 50 ml of duplicating fluid or alcohol into another jar. Next, combine the 50 ml of water with the 50 ml of duplicating fluid into another jar. Mix well. Students should observe that the level of the two liquids when mixed is not equal 100 ml. What happened to the missing liquid? Have the students infer what happened. Guide them toward a discussion of molecules.

When mixed together, the combined molecules of water and duplicating fluid fit together better than when they are alone. As a result they take up less space. It is similar to mixing together sand and marbles. If you pour sand into a container with marbles, some of the sand will find room in the spaces between the marbles and the combined volume will not total the two separate volumes.

Further Challenges:

- ☐ What will happen if you combine 25 ml of water and 25 ml of duplicating fluid? Predict the results.
- ☐ What will happen if you combine 100 ml of water and 100 ml of duplicating fluid? Predict the results.



Reference:

Friedl, Alfred E. *Teaching Science to Children*. New York: Random House,

Safety: Both alcohol and duplicating fluid are flammable and poisonous. Close supervision is essential to avoid injury.

Solutions To Crystals (*Rock Candy*)

by Linda Vance and Rose West

Focus:

Growing rock candy crystals is a great activity for learning about solutions, saturated solutions, mixtures, expansion and contraction. All of these terms can be discussed while mixing the sugar crystal solution.

Challenge:

What can be discovered about dissolving, solutions, saturated solutions, and mixtures while observing a demonstration of how to make rock candy?

Materials and Equipment:

Water	Granulated sugar
Pyrex beaker	Stir rod
Wooden stick	Heat source
Tripod stand for beaker	Plastic tumbler
Small bolt (or other weight)	Cheesecloth

Procedure:

Pour 1/2 cup water into the glass beaker and place it over an appropriate heat source. (*A Pyrex beaker works well because students can observe the sugar dissolving*). Bring the water to a boil. Gradually stir in sugar until no more will dissolve (about 2/3 cups). Pour the sugar water into a plastic tumbler. Tie a string slightly shorter than the depth of the tumbler onto the wooden stick. Tie a small bolt or some object which will not float onto the other end of the stick. Place the string in the sugar solution in a warm place where it will not be disturbed. To keep dirt out and to allow evaporation, a piece of cheesecloth may be placed on top. Wait patiently; it may take several days for the crystals to fully develop.

You may wish to lead students through a discussion of concepts related to this activity. Some topics for discussion might include dissolving, solutions, saturated solutions, and mixtures

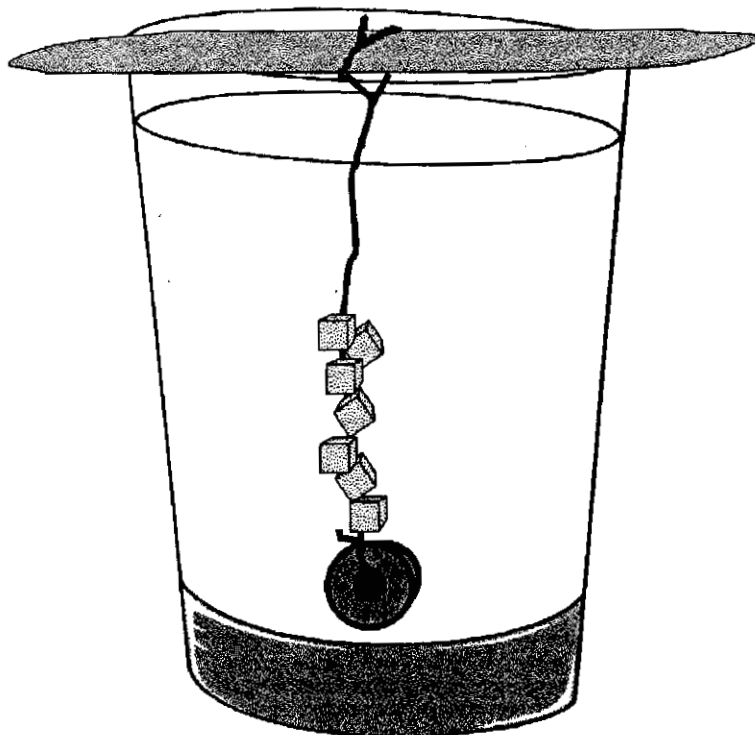
Further Challenges:

- ☐ Try making rock candy at home under parent supervision.
- ☐ Grow crystals using other substances: salt, Epsom salts (magnesium sulfate), alum.
- ☐ Observe different crystals using a hand lens. (Mica, granite, quartz, sugar, table salt. This could be done while visiting other places. Many vacation spots sell nice crystals for little money.)
- ☐ Teachers can demonstrate other crystal formations using potassium ferricyanide, copper sulfate, potash alum.

References:

Freeman, Mae and Ira. (1973) *Fun With Chemistry*. New York, NY: Scholastic Book Service.

Holden, A. and P. Morrison. (1982) *Crystals and Crystal Growing*. Cambridge, MA: MIT Press.



Growing Perfect Crystals In Minutes

by Michael J. Demchik

Focus:

Seven classes of crystals can be prepared through the use of a micro-projector.

Safety: Whenever using chemicals in the classroom, be sure to follow all label directions and warnings.

Challenge:

Can you identify the various shapes of the crystals formed from each of the saturated solutions given? What factors affect the rate of crystal formation? Why do the colors of some crystals change after the process of evaporation starts?

Materials and Equipment:

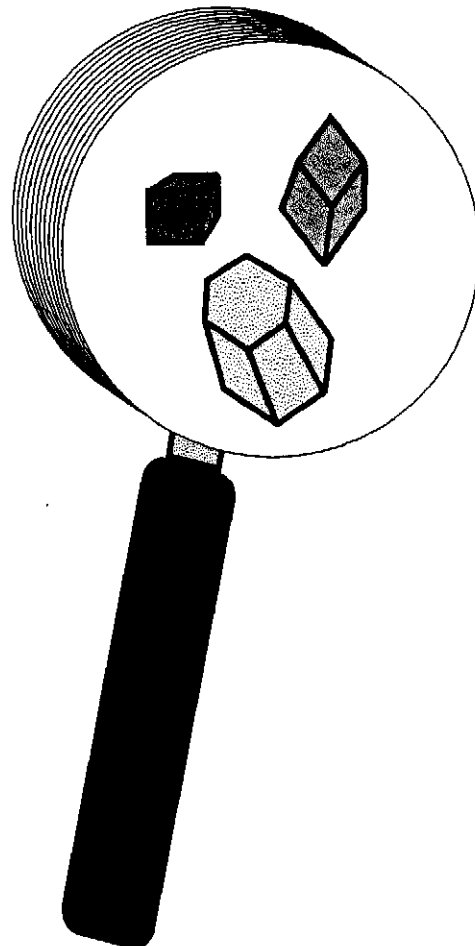
Micro-projector	Glass slides
Copper sulfate	Nickel sulfate
Sodium nitrate	Potassium chlorate
Eyedropper	Beakers or jars
Sodium chloride	Sodium triphosphate
Potassium nitrate	

Procedure:

Turn on the micro-projector. Allow it to warm up for a few minutes. Set the objective in line with the stage and focus with a drop of water on the slide. With an eyedropper place one drop of saturated solution of copper sulfate on the slide and place the slide on the stage and focus. Observe while the water evaporates. Within a short time crystals begin to form along the periphery. The specific color of the compound gradually changes to black because of the quantity of solid precipitated. As the solution becomes reduced in amount, a noticeable formation of gradients will occur. It is at this point that the perfect crystals begin to precipitate. Search the slide for the presence of others or focus on the one found and the crystal will grow before your eyes. Try the other samples.

Further Challenges:

- ☐ Use reference materials to identify the molecular causes of different types of crystals.
- ☐ Use a tweezers to remove individual crystals from the micro-projector. Individual students may wish to examine these crystals with hand lenses or microscopes.



Separating Mixtures

by Linda Vance and Rose West

Focus:

Given a few simple materials students will use problem solving skills to separate a mixture. While introducing the concept of mixtures and compounds students will discover that mixtures can be separated by using various physical methods.

Challenge:

To separate a mixture of four substances based on their known properties.

Materials and Equipment:

Cup containing salt
Cup containing sand
Cup containing gravel
Cup containing iron filings
Tea strainer or screening
Ring stand with funnel support

Water
Magnets
Funnel
Filter paper
Stirring stick
Beakers

Procedure:

Have lab stations set up ahead of time with the materials as listed above. This is an inquiry lab, therefore the only

instructions of help might be on how to fold filter paper to fit into the funnel. Instruct the students to combine all of the substances from the small cups into a beaker. After the substances are combined, tell them to now separate them with the materials provided. You may wish to provide a data table like the one suggested below.

Add water and then put the water mixture through the filter paper (SAND)

Allow the water to evaporate (SALT). This is optional to speed the process the water can be heated.

Further Challenge:

- ☐ What are some properties of iron filings? *They can be drawn to a magnet.*
- ☐ What property does salt have that sand does not? *Salt dissolves in water.*
- ☐ Investigate other ways of separating mixtures such as chromatography or distillation.
- ☐ Do a lab involving chemical change to see that sometimes things are mixed and cannot be separated. *(Chemical change as opposed to physical change)*

DATA TABLE

<i>Substance</i>	<i>Method</i>
Iron filings:	<i>Pulled out with a magnet.</i>
Gravel:	<i>Sifted out with a tea strainer .</i>
Sand:	<i>Added water and put the mixture through filter paper.</i>
Salt:	<i>Allowed water to evaporate.</i>

The Power Of Salt

by Mildred Moseman

Focus:

Calcium chloride (*road salt*) is very useful for removing snow from roads in colder climates. In some parts of the country where the climate is dry, these salts can remain in the local environment and enter the water supply. Snow removal practices throughout these areas of the country can create a situation with the potentially dangerous environmental consequences.

Challenge:

Road salt, used to keep traffic going on glazed roads, mixes with snow and ice and can enter the water table affecting drinking water. Is there a way to detect the amount of salt found in melted snow or ice? How far from the origin does salt affect snow?

Materials and Equipment:

Test tubes for each student
Snow samples (*from various locations*)
Distilled water
Silver nitrate
Eye droppers

Procedure:

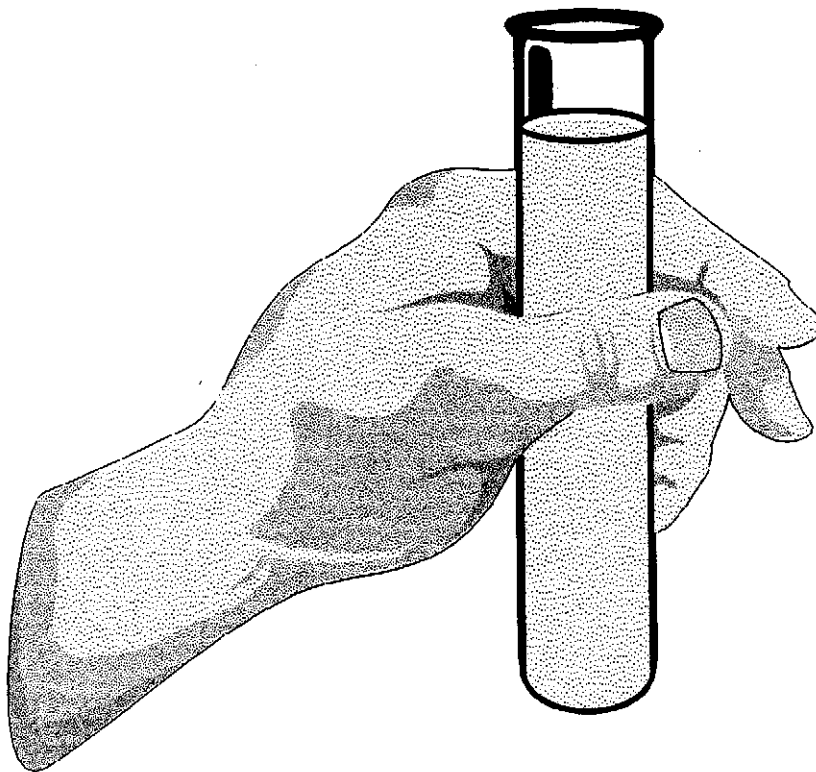
Fill test tubes with snow or melted ice from various locations and label. Fill one test tube with some distilled water. This will serve as a control for the investigation. Into each test tube put 3 drops of silver nitrate. (*This may be procured from a high school chemistry lab or science supply house.*) The cloudier the solution becomes, the higher the salt concentration is likely to be.

Further Challenges:

☐ Create samples of known dilutions of calcium chloride to use as comparisons to gathered samples.

- ☐ Why can road salt be dangerous to the public health?
- ☐ What is the ecological danger due to salt?
- ☐ Why does salt break the bond between the road and the ice?

Safety: As with all activities involving chemicals, refer to labeling for appropriate safety precautions and first aid information.



Water Magic

by Sue Dale Tunnicliffe

Focus:

This investigation focuses on the concept of dilution.

Challenge:

If you are given a drink made from a concentrated powder such as iced tea, orange drink, punch, or other soft drink, what do you do if its taste is too strong? What do you do if it tastes too watery? How do you dilute the drink to suit your taste? How could you make the color of a given solution seem to disappear?

If students have had experience in designing their own investigations, you may wish to have them develop their own method of determining the point at which the solution is so diluted that the color can no longer be seen. If they are unsuccessful in this attempt, the procedures below may serve as a guide.

Materials and Equipment:

Powdered drink mix
Measuring cups

Water
Plastic buckets

Procedure:

The teacher will mix a large pitcher of powdered soft drink. Each group will fill one measuring cup (or marked jar) with 100 ml of the solution. They will then draw 100 ml of clear water from their bucket of water. The clear water will then be poured into the cup of soft drink. Students will then note on the chart below whether or not the color of the soft drink could still be seen at this one-half strength

solution. Next, one-half (100 ml) of the new solution will be discarded. Repeat the procedure of adding and discarding water and solution until the color of the soft drink is no longer visible. Through this method, students should be able to determine the point where the solution is so diluted that the color can no longer be seen.

Each time half of the contents of the cup are withdrawn and the volume left is topped up with water, the color is diluted. Eventually the color can not be seen with the naked eye. Some children may like the idea of adding more and more water to the original volume. Allow them to try this method if a large enough container can be located.

Further Challenges:

- ☐ How does the point of dilution where the color is no longer visible compare to the point of dilution where the soft drink can no longer be tasted?
- ☐ How does the concept of dilution relate to environmental pollution?
- ☐ How does the method of dilution used in this investigation relate to radioactive decay and half-life?
- ☐ Are there other ways of removing color? (Removing a stain from clothing, or bleaching color from hair? What household chemicals are used for this type of thing?)
- ☐ What other sort of things do we intentionally dilute?

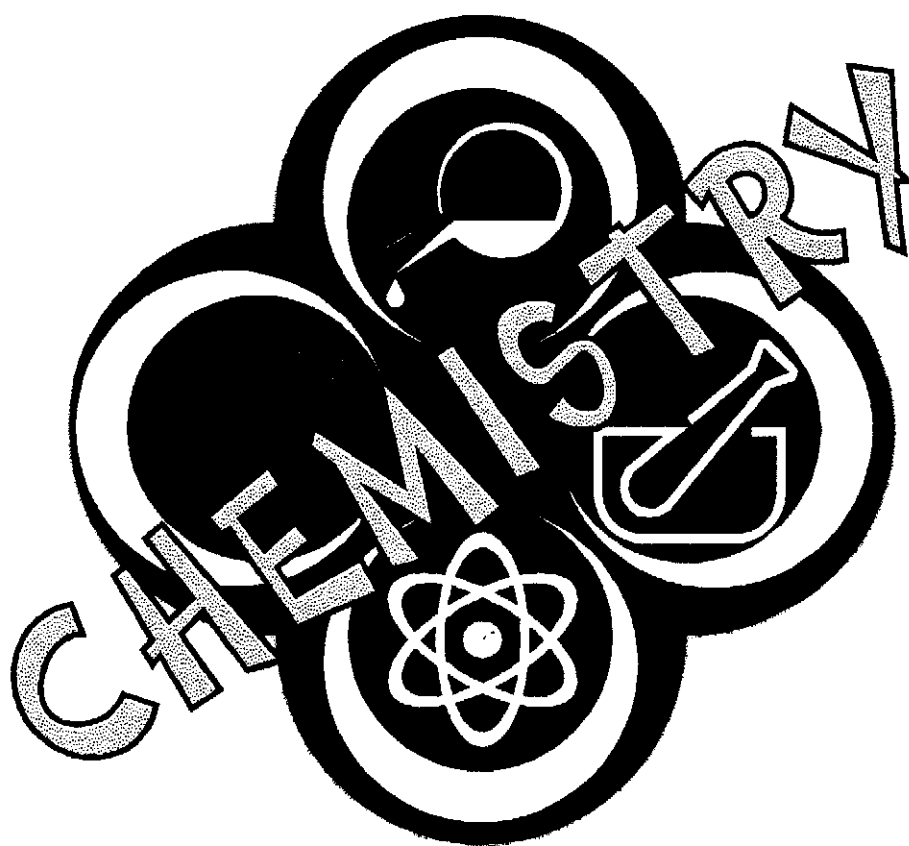
COLOR DILUTION CHART

(Indicate by circling whether color is visible for each trial.)

trial 1 full strength - yes no
trial 2 1/2 strength - yes no
trial 2 1/4 strength - yes no
trial 2 1/8 strength - yes no

trial 2 1/16 strength - yes no
trial 2 1/32 strength - yes no
trial 2 1/64 strength - yes no
trial 2 1/128 strength - yes no

CHAPTER - 11



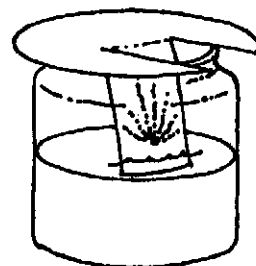
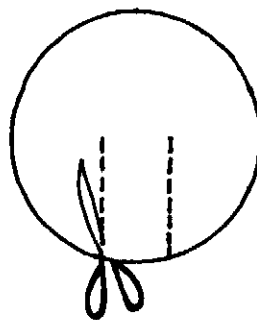
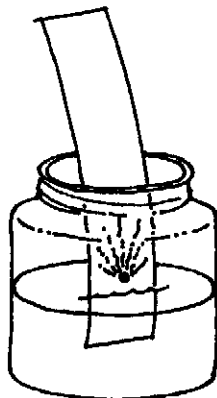
Somewhere Over The Rainbow

by Thomas E. Thompson

Focus:

This activity can be used at both the primary and intermediate grades. For younger children the emphasis can be on the concepts of primary and secondary colors; or on the skills of observing, predicting, or inferring.

For older children the emphasis can be on the concepts of absorption or chromatography and the skill of hypothesizing. The activity enables one to stress both concept and process simultaneously.



Challenge:

Separate the individual pigment components found in the inks in felt-tip pens.

Materials and Equipment:

Felt-tip pens	Filter paper
Clear containers	Water
Ruler	Timer

Procedure:

Chromatography is a common laboratory procedure used to separate and identify mixtures of chemical compounds. This activity uses the same basic procedure, but uses water instead of alcohol for the solvent, and ink found in felt-tip pens instead of other chemicals for the absorbing agent.

The basic procedure to follow is: Fill a baby food jar with approximately 25 ml of water. Place a small dot of ink about 2 cm from one end of the rectangular piece of filter paper. (If you do not have filter paper, some white paper towels or coffee filters can be substituted.) Insert the paper into the water inside the clear container as shown below. (Baby food jars work well for containers.) It is important that the colored dot remain above the surface of the water.

If a circular piece of filter paper is used, make two parallel cuts toward the center and place the small dot as shown on the suspended strip. Fold the strip down so that it is perpendicular to the circular disc and insert into the water in the container.

As the water is absorbed up the filter paper, it will "carry" the ink pigment up the strip and deposit the ink pigment in a fan shaped pattern. Secondary colors will break up into a variety of other colors. Brown and black felt-tip pens give the most dramatic effects. However, one might be surprised when a color such as gray is used.

Further Challenges:

☐ Once the basic procedure is mastered, be prepared for the children to begin to ask a number of "what if?" type questions. For example, a few possibilities are:

- What if I used a different brand of felt-tip pen?
- What if I used a line instead of a dot?
- What if I used hot water?
- What if one color dot is placed on top of another?
- What if I used a different liquid?
- What if I varied the type of paper used?

☐ Display strips of filter paper with the color separation patterns of two or more combined colored dots. Challenge students to determine which colors were used. This challenge might require additional inquiry.

☐ Children could also make up new patterns and have other children play detective.

Examining Ink

by Michael J. Demchik

Focus:

Ink is either water or alcohol based and contains ingredients for color and binding.

Challenge:

What is the composition of standard ink? Can it be separated? Can you determine whether a particular kind of ink is alcohol or water based?

Materials and Equipment:

Ring stand and clamp
Thermometers
Filter paper
Rubber hose
Burner or heat source

Beakers
Test tubes
Ink
Glass tubing

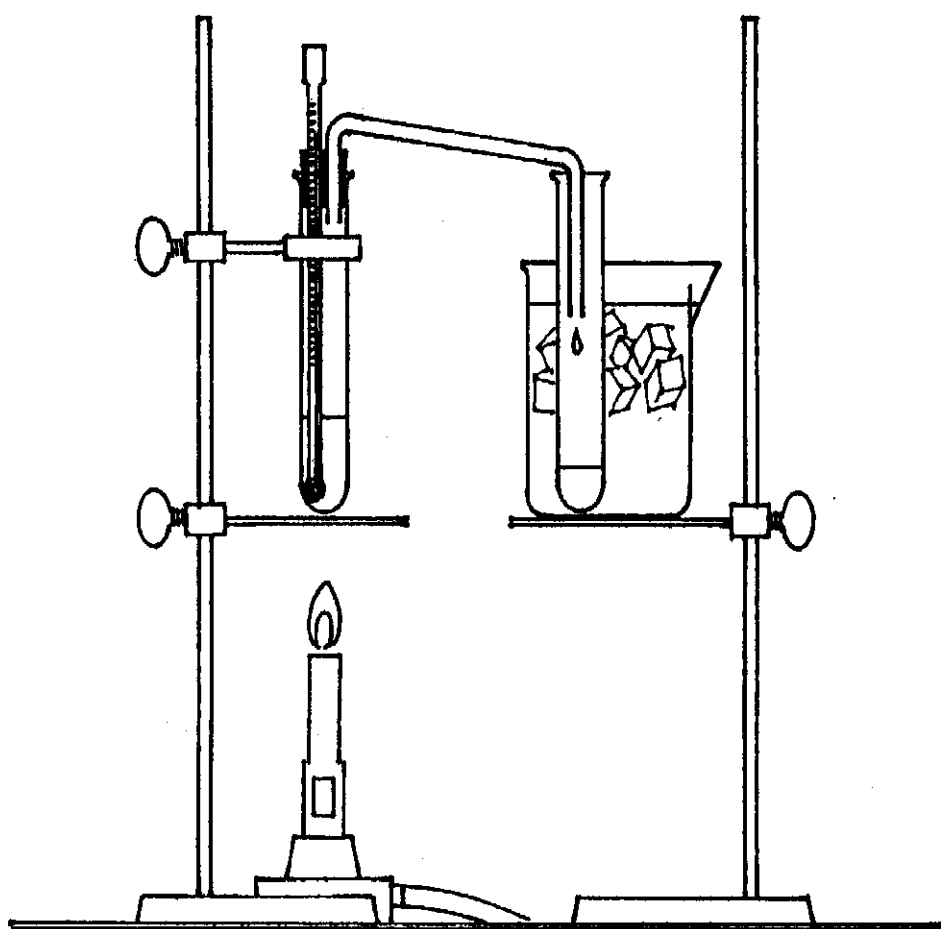
Procedure:

Set up the apparatus as shown in the figure. Fill the outside beaker with cold water. Heat the sample of ink placed into the test tube with an alcohol burner or Bunsen burner. Record the temperature and observe the changes that take place. A liquid collects in the test tube. After heating the sample almost to dryness, remove from the flame and examine the residue.

Further Challenges:

- ☐ Look up the boiling points for water and alcohol. Could this information help determine the composition of ink?
- ☐ Repeat the activity and take the temperature every 30 seconds. Plot a graph of the results. What does the plateau indicate?

- ☐ Try other approved liquids to see if they separate.



Safety: Eye protection should be worn any time liquids are heated in glass containers. Take appropriate precautions in dealing with heat sources and flammable liquids. Most inks also are hard to remove from anything if spilled. You may want to use washable ink for this activity.

Secret Handwriting

by Edward L. Shaw, Jr.

Focus:

Code writing using lemon juice on regular notebook paper is an interesting and inexpensive way for elementary school children to practice handwriting skills as well as participating in a science experiment. Paper is made from wood byproducts; wood contains cellulose. The wood cellulose in the paper, when combined with an acidic solution such as lemon juice, will produce sugar. When heat is applied, the sugar caramelizes and turns brown.

Materials and Equipment:

Lemon juice	Cotton swabs
Notebook paper	Baby food jars
Graduated cylinder	Paper towels
Heat source	

Procedure:

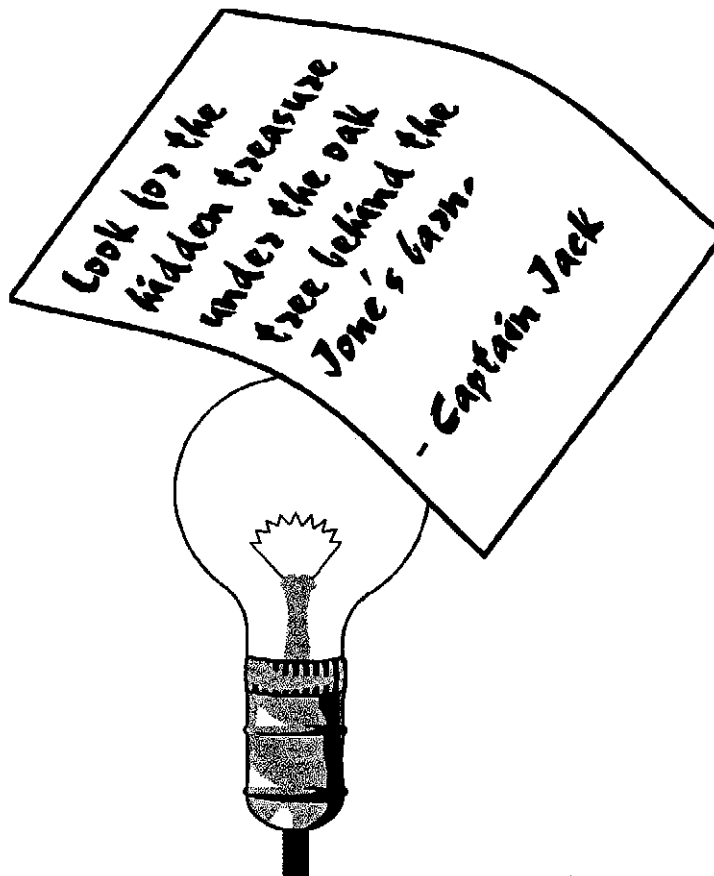
Each group of students will need should be given bottles of lemon juice, cotton swabs, notebook and paper towel for clean-up. A good substitute for a cotton swab is a fountain pen if available. Allow the students to practice writing brief secret messages with the cotton swabs without using the lemon juice. After they have had a chance to practice their messages, allow students to dip their swabs into the lemon juice and write their messages. Caution them not to use an excess amount of the juice for each letter.

For safety reasons, the teacher may wish to do the next part for students. If this part of the activity is done by students, close supervision should be applied. Each paper is passed over the heat source until the message appears. Students should be warned to repeat the investigation only with adult supervision. The teacher can allow students to exchange messages and display their best ones around the room.

Further Challenges:

- ☐ Have students determine if more or less lemon juice will produce the same quality message.
- ☐ Determine if there are other solutions, such as vinegar or pickle juice which will produce the same type of message.
- ☐ Ask if there are other types of paper products that will produce the secret message.
- ☐ Write a short mystery story that involves secret messages written in invisible ink.

Safety: Take appropriate precautions with all heat sources used for this activity. Light bulbs and hot plates get hot enough to cause severe burns or start fires. While other heat sources such as candles and alcohol burners will work, these should be avoided as they may readily cause the paper to burn. As a safety precaution, a fire extinguisher or bucket of water should be kept nearby.



PCJ or PURPLE CABBAGE JUICE

by Yvonne A. Johnson

Focus:

Using purple cabbage juice as an indicator, children will be able to tell if materials are acidic, basic, or neutral.

Challenge:

Chemicals can be grouped together because they share common properties. Acids neutralize a base, and contain hydrogen. They have a sharp, sour taste. Bases neutralize acids and contain a hydroxide ion. They may feel slippery or soapy.

Materials and Equipment:

Wooden or plastic spoon	Red cabbage
Glass dish (Pyrex)	Vinegar
Clear plastic cups (1 oz size)	Ammonia
Glass jar, quart or gallon	

Procedure:

To prepare purple cabbage juice (PCJ) place the shredded cabbage in the glass bowl. Do not use any metal utensils in doing this so that there cannot be a metallic reaction with the PCJ. Cover the shredded cabbage with cold water. Place on the stove and heat. You may use the wooden or plastic spoon to press the cabbage down in the bowl. When the water is blue, pour it off into a clean glass jar. Repeat this process until you have enough PCJ to use for your class. Store in the refrigerator. It will keep 2-3 weeks if refrigerated.

Give the students 3 - 1 oz clear plastic cups which will be placed in a row on their desk or lab table. Pour the same amount of PCJ in each cup. Use the middle cup as the constant. In the left hand cup, add vinegar (*a weak acid*) until there is a color change. The PCJ will turn pink. In the right hand cup, add ammonia (*a weak*

base) until there is a color change. The PCJ will turn green.

Using these three cups for comparison, the student can test a variety of other materials to determine if they are acidic or basic. If there is not an apparent change, the material is neutral (*neither acidic nor basic*).

Further Challenges:

- ☐ Collect a variety of materials to test such as: apple juice, baking soda, baking powder, soda water, lemon juice, and saliva.
- ☐ Investigate to find other methods of determining if materials are acidic or basic.



Color Magic With Fruits And Vegetables

by Stephen C. Blume

Focus:

Children can make indicators of acids and bases from many fruits and vegetables. After observing the color changes of the indicators, they can use the indicators to determine acids and bases in their homes or the relative strength of different acids or bases.

Challenge:

How can you make an indicator of acids and bases out of fruits and vegetables? What color does your indicator change to when an acid is added? What color does your indicator change to when a base is added?

Materials and Equipment:

Clear ammonia (non-sudsy)	Alcohol
Clear vinegar	Spoon
Fruits and vegetables (assorted)	Medicine droppers
Baby food jars	Containers for rinsing
Containers for dumping	

Procedure:

Acid/base indicators can be made from many other substances. In this activity children will make indicators of

acids and bases from fruits and vegetables such as blueberries, cherries, apple skins, beets, onions, and purple cabbage leaves and then test the indicators with an acid and a base.

This is a good activity to follow classroom experiences with acids and bases using litmus paper, phenolphthalein, or bromothymol blue. The activity can be performed individually, as a whole class activity, or in small groups students. Also, the materials and directions can be set up as a learning center.

Select a fruit or vegetable for your acid/base indicator. Cut it into small pieces. Place the pieces into a baby food jar, and fill the jar 1/2 full with alcohol. Then, mash the indicator with a spoon. Allow the fruit or vegetable to soak in the alcohol for 15 minutes or until the alcohol takes on the color of the fruit or vegetable. Then, drain off the liquid into two clean baby food jars. This liquid can now be used to check for acids and bases.

Test each liquid and observe and record any color changes by adding drops of vinegar (an acid) to one baby food jar and drops of ammonia to the other baby food jar. Record your observations of any color changes in a chart.

Name of Indicator	Color	Color with acid	Color with base
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Further Challenges:

☐ Once an indicator has been changed to a different color with an acid, do you think that it can be changed back to its original color by adding a base? Try it and see! How can you explain what happens?

☐ Once an indicator has been changed to a different color with a base, do you think that it can be changed back to its original color by adding an acid? Try it and see! How can you explain what happens?

☐ What other fruits and vegetables might make indicators of acids or bases? Try them. (You might want to try purple grape juice or cherries.)

☐ Do you think that flower parts might be indicators of acids or bases? Try some. (You might want to try daisy petals, rose petals, or red poinsettia leaves.)

☐ What other household substances might be acids or bases? Add drops of various household liquids to an indicator, or add household powders to water and add drops to an indicator. (Liquids you might want to try might include shampoo, liquid detergent, fruit juices, soft drinks, pickle juice, milk, and window cleaner. Powders you might want to try might include baking soda, cream of tartar, cleanser, and soap powder.)

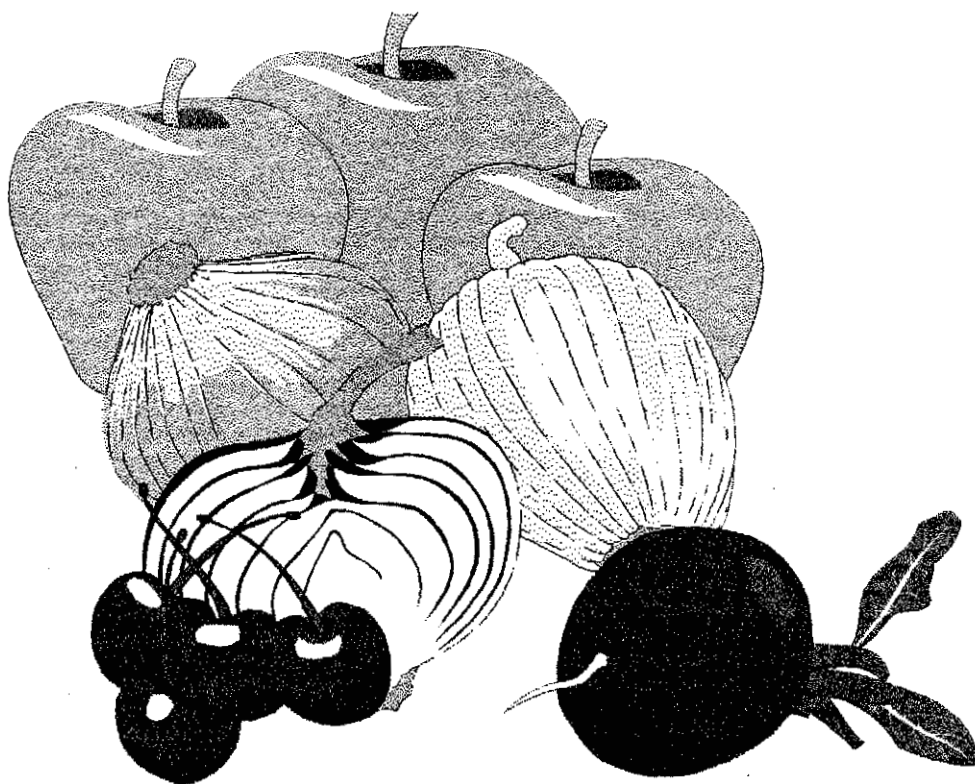
☐ How many drops does it take to change the color of your indicator? Count and record the number of drops that it takes to change the color of your indicator using acids that you have discovered. For example, which takes more drops to change your indicator: apple juice, orange juice, or grapefruit juice? How can you explain why one juice takes more drops than another juice?

References:

Cobb, Vicki. (1972). *More Science Experiments You Can Eat*. New York: J. B. Lippincott.

Liem, Tik L. (1981). *Invitations to Science Inquiry*. Lexington, MA: Ginn Press.

Melbane, R. C. and T. R. Rybolt. (1985). *Adventures with Atoms and Molecules*. Hillside, NJ: Enslow Publishers, Inc.



A SEARCH FOR HIDDEN PROPERTIES

by Bonnie Barr

Focus:

Solutions which look, smell and feel alike may have different hidden properties. Hidden properties are those which cannot be observed directly. A major responsibility of a chemist is to determine the hidden properties of matter. The hidden properties may affect how chemicals interact. Predicting interaction is an important job of a chemist. In this activity students as young as kindergartners can get the feel for hidden properties of matter.

Challenge:

What colorless solutions cause "the red cloth" to turn blue? Will all red cloth turn blue in that solution? What common foods turn purple cabbage juice red? What hidden properties are similar in the "fizz" of baking powder and water, soda pop and alka seltzer?

Materials and Equipment:

Water

Baking soda/water solution (1 Tbs. baking soda to 1 quart of water)

Citric acid (Fruit Fresh), (1 Tbs. citric acid to 1 quart of water)

Cotton cloth dyed with Congo red stain (2" x2" squares)

Red cotton cloth (2" x2" squares)

Plastic cups per group (labeled A & B)

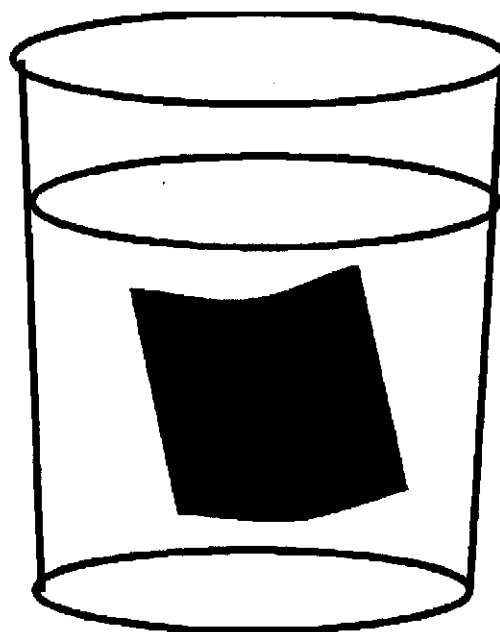
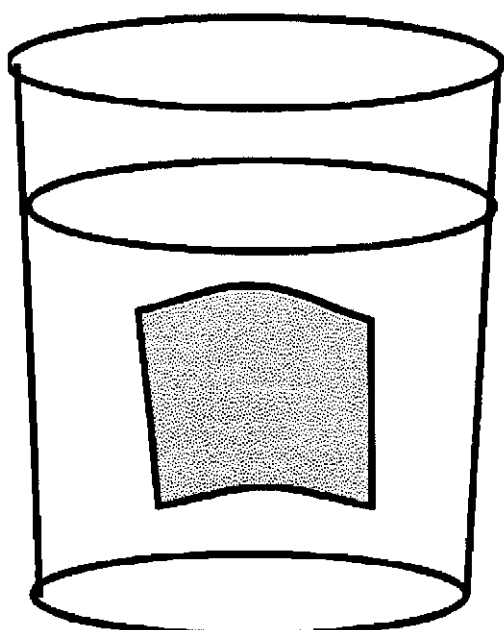
Popsicle sticks

Procedure:

Have students work in small groups. Tell the students that one of the major jobs of a chemist is to determine properties of solutions. Give students two plastic cups one marked "A" (baking soda solution) and the other "B" (citric acid solution). Each cup will be filled with a liquid. Instruct students to use their sense of sight, smell and touch to determine if the solutions in the cup are alike or not. The two solutions will look, smell and feel the same. (Although these solutions are safe, do not have students taste the solutions.)

After the students have had the opportunity to examine the solutions, ask them, based on what they have observed, if they think it is the same solution in both cups. Most students will assume that the solutions are the same based on first observation.

Next, give each group a square of red cotton cloth and a popsicle stick. Instruct students to place the square in the solution in either cup "A" or "B" and stir the cloth in the solution. Remove the cloth from the solution with the stick and put in into the second solution. Stir the cloth again. The cloth may be transferred between the two cups several times. Students should record their observations.



Give a square of the Congo red dyed cloth and popsicle stick to each group. Have the groups repeat the procedures above. The square will turn blue in the citric acid solution and back to red in the baking soda solution. The reaction is reversible. Ask the students if they think the solutions are the same based on their new observations.

Ask the students what variables need to be studied in order to better understand the hidden properties of the two solutions. A variety of variables are likely to be mentioned. Make sure the list includes the following: Will any red cloth change color when transferred from one solution to the other? Will other substances than the two solutions cause the cloth to change color? Set up investigations to answer the questions. Try dipping a variety of different pieces of red cloth into the two solutions. (Only the cloth dyed with Congo red changes color.)

Try dipping the Congo red dyed cloth into a variety of solutions such as vinegar, orange juice, scouring powder, diluted ammonia. The cloth will turn blue in vinegar or orange juice and back to red in scouring powder and diluted ammonia.

Ask the students to summarize what they have learned about the hidden properties of the materials involved in these investigations. Some conclusions are: a) Hidden properties of the red cloth (Congo red dyed) cause it to change color. b) Solutions that look, feel, and smell the same may have different hidden properties. c) Solutions which cause the red cloth to change blue have a similar hidden property; solutions which change the cloth back to red have a similar hidden property. d) Solutions which look, smell and feel differently may have a hidden property that is the same.

Further Challenges:

☐ Obtain purple cabbage juice by boiling a quarter of a head of purple cabbage in a gallon of water. Try mixing the purple cabbage juice in common, safe to use household foods/chemicals. Which cause the juice to change red? Green? Is the strength of the hidden property *the same in* all substances that cause the purple cabbage juice to turn red? (No.) How can you tell? (With the same dilution some mixtures produce a darker hue of red than others.) Conclusion: Hidden properties of a substance can vary in both quality and quantity.

☐ Using purple cabbage juice, determine if various brands of shampoo have a similar hidden property.

☐ Make pitchers of fresh, frozen, dehydrated, and canned orange juice at concentrations suitable for drinking. Add one half cup of each to four cups. Add one half cup of purple cabbage juice to each orange juice sample. Do all mixtures change to the same color hue? (No.) Which orange juice sample has the most of the hidden property? (The juice which produces the deepest red hue.)

☐ Insert a 25 cm length of flexible plastic tubing into a one hole stopper. Make sure the fit is tight. (If not, seal with plastiscine.) Unseal a bottle of soda pop. Quickly seal the bottle with the stopper. Allow the gas from the soda pop to bubble through the tubing into a small container filled with purple cabbage juice. How does the "fizz" change the cabbage juice? Set up similar investigations in which the fizz of a baking powder/water solution and an alka seltzer solution are bubbled into purple cabbage juice. Describe how the fizz from each solution affects the purple cabbage juice. (Conclusion: Gases produced in a variety of different ways may be the same gas if their hidden properties are the same.)

Fire Egg-Stinguisher

by Carol Van De Walle

Focus:

This activity features a chemical change using materials the students are familiar with and which are easy to obtain. The students will become familiar with a chemical change and recognize some common characteristics of carbon dioxide. In addition, they will learn much about the egg.

Egg shells are primarily calcium carbonate. Vinegar is an acid. Calcium carbonate reacts to vinegar in a chemical reaction which gives off carbon dioxide. Carbon dioxide has no taste, no odor, no color, is not combustible, and is more dense than air.

Challenges:

Does the strength of the vinegar affect the chemical reactions? Does the quantity of vinegar or egg shell affect the speed of the chemical reaction? Does the height of the candle affect the speed of extinguishing the flame? If so, what could be the explanation?

Capture some of the gas given off in the chemical reaction and put it through limewater to further demonstrate that it is carbon dioxide.

Materials and Equipment:

Birthday candles	Crushed egg shells,
Vinegar	Wooden matches
Beakers (<i>Jars may be substituted</i>)	Clay
Stop watch (<i>or clock with second hand</i>)	

Procedure:

Place about 20 - 25 ml of egg shell into a container. Add an equal amount of vinegar. Record your observations; direct students to note a gas is given off. Can they determine what the gas is from this information?

Next, in a clean beaker, place a small piece of clay in the bottom; insert candle into clay holder. Add egg shells. Light the candle carefully, then quickly but gently pour vinegar down the side of the beaker. Start timing as soon as bubbling begins. Stop when candle goes out. Record time. You may wish to repeat the investigation to verify

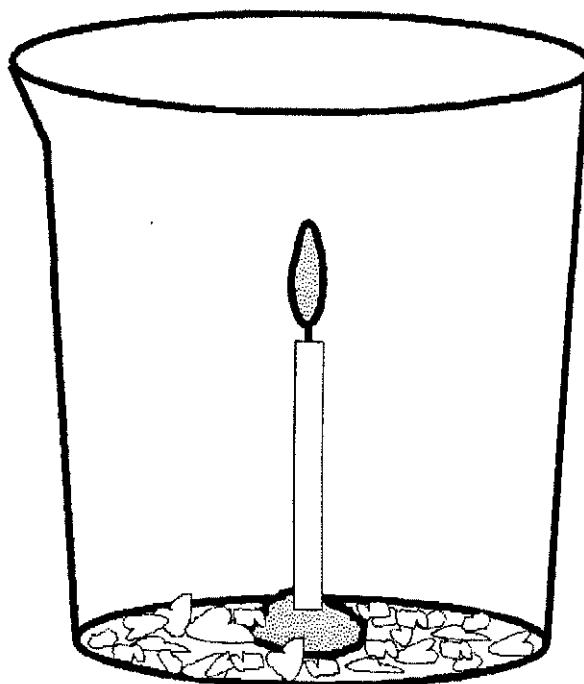
results. Discuss observations about the gas that was formed.

Further Challenges:

- ☐ Repeat the investigation but change one variable, such as the amount of shell or the amount of vinegar.
- ☐ Continue to observe the egg shell in vinegar for several days, record your observations.
- ☐ Try assorted candle sizes. Does the thickness or height of the candle affect the time to extinguish the flame?

Reference:

De Vito, A. (1982) *Teaching With Eggs*. West Lafayette, IN: Creative Ventures, Inc.



A Gas Problem

by David R. Stronck

Focus:

People can suffer distress from various pains in the stomach. They can have "gas pains" which sometimes are relieved by burping (i.e., emitting some gases.) Often they turn to the use of over-the-counter medicines that are designed to help an upset stomach. Youngsters can do a series of chemical reactions that will help them understand reactions that occur inside their bodies.

Challenge:

Does the same gas (*carbon dioxide*) come from a variety of sources, e.g., from your stomach, your lungs, and some chemicals?

Materials and Equipment:

Baby food jars and caps

Alka Seltzer tablets

Plastic teaspoons

Clear plastic cups

Plastic aquarium tubing (apx. 18" lengths)

Baking soda

Tums tablets

Vinegar

Water

Modeling clay

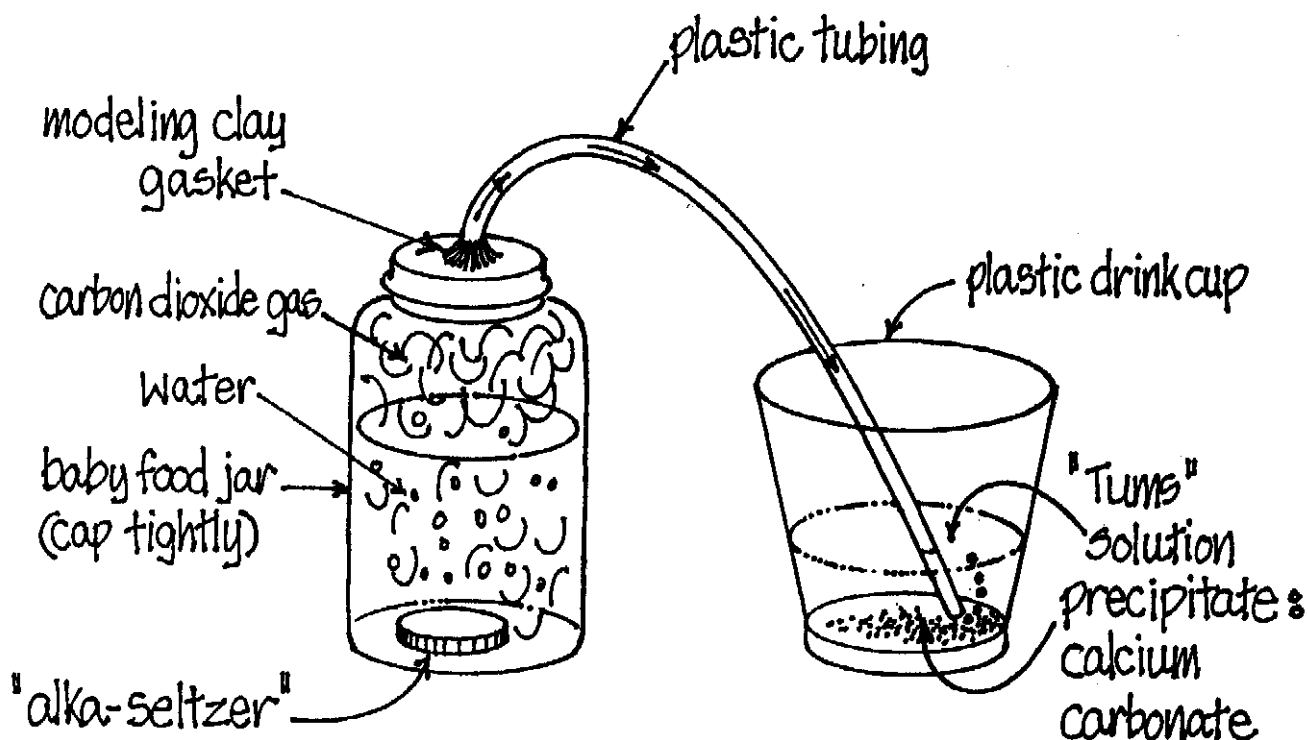
Procedure:

Ask the students to explain what is going on when a person has gas pains in their stomach. Can any student explain what antacid tablets do to help? Invite the youngsters to observe the action of these tablets by doing the following:

Add enough water to fill most of a small jar or cup. Then drop in a Tums tablet. Use a clock or watch to observe how much time passes before the tablet is dissolved. Into a second jar or cup, add enough vinegar to more than cover the bottom surface. Add water to fill most of the jar. Add another Tums tablet to this second jar or cup. Record the amount of time before this second tablet is dissolved. Which reaction went faster?

Pour a third of the contents of the first jar (in which a Tums tablet has been dissolved) into two additional jars or cups. Each team of students will now have three jars with Tums solutions.

To construct the gas generator use a hammer and a nail to punch a small hole in the metal cap. Snugly fit one end of



the plastic tubing through this hole in the center of the cap. The area between the tubing and the hole must be made airtight. This may be accomplished by plugging any gaps with wads of modeling clay.

After constructing the gas generator as shown, add enough water to the baby food jar to fill it slightly more than halfway. Drop in an Alka Seltzer tablet. Quickly cover the jar with its cap assembly. Carbon dioxide gas will come through the tubing from the dissolving Alka Seltzer tablet. Place the other end of the tubing into the Tums solution of one cup. What can be observed? (*Calcium ions from the Tums tablet can react with carbon dioxide gas in water to form calcium carbonate, a white powdery substance that dissolves poorly in water.*) If a white powder appears in the water, will the addition of some vinegar to the water make this white powder disappear? (*Vinegar contains acetic acid that may allow the calcium ions to remain dissolved in the water as calcium acetate.*) Discard the contents of this jar or cup.

Discard the contents of the babyfood jar gas generator. Wash out the inside of the jar. Add enough water to fill more than half of the jar. Then add half a teaspoonful of baking soda to this water. Stir it until it dissolves. Finally add at least a teaspoonful of vinegar. Quickly put on the cap with the plastic tubing. Place the other end of the tubing into one of the cups with a dissolved Tums tablet. Does this gas give the same reaction that occurred with the gas from the Alka Seltzer? Discard the contents of this jar or cup.

Remove the tubing from the babyfood jar gas generator. Put one end of the tubing in your mouth and insert the other end of the tubing into one of the jars with a solution of a dissolved Tums tablet. Exhale air from your lungs into the cup. Does the gas from your lungs give the same reaction as the gas from the Alka Seltzer and/or the gas from the vinegar and baking soda reaction?

Discuss with the students that the gas carbon dioxide reacts with calcium ions in water to precipitate the rocklike material calcium carbonate.

Further Challenges:

☐ Invite the students to change the quantities of any of the chemicals to observe possible differences. Note that vinegar has the opposite effect on reactions than has baking soda.

Plastic Bag Chemistry

by Bonnie Barr

Focus:

In the following activity students will be able to observe three indicators of a chemical change: change in color, gas production, and change in temperature. Students will have the opportunity to explore exothermic (*resulting in an increase in temperature*) and endothermic (*resulting in a decrease in temperature*) changes. The activity attempts to use a problem solving approach to monitor factors affecting chemical changes.

Challenge:

What indicators can be used to determine if the chemical change resulting from the mixture of materials that look the same is the same? How does a change in the amount of one component of a reaction affect the chemical change? Is it possible to predict the temperature of a specific endothermic or exothermic change?

Materials and Equipment:

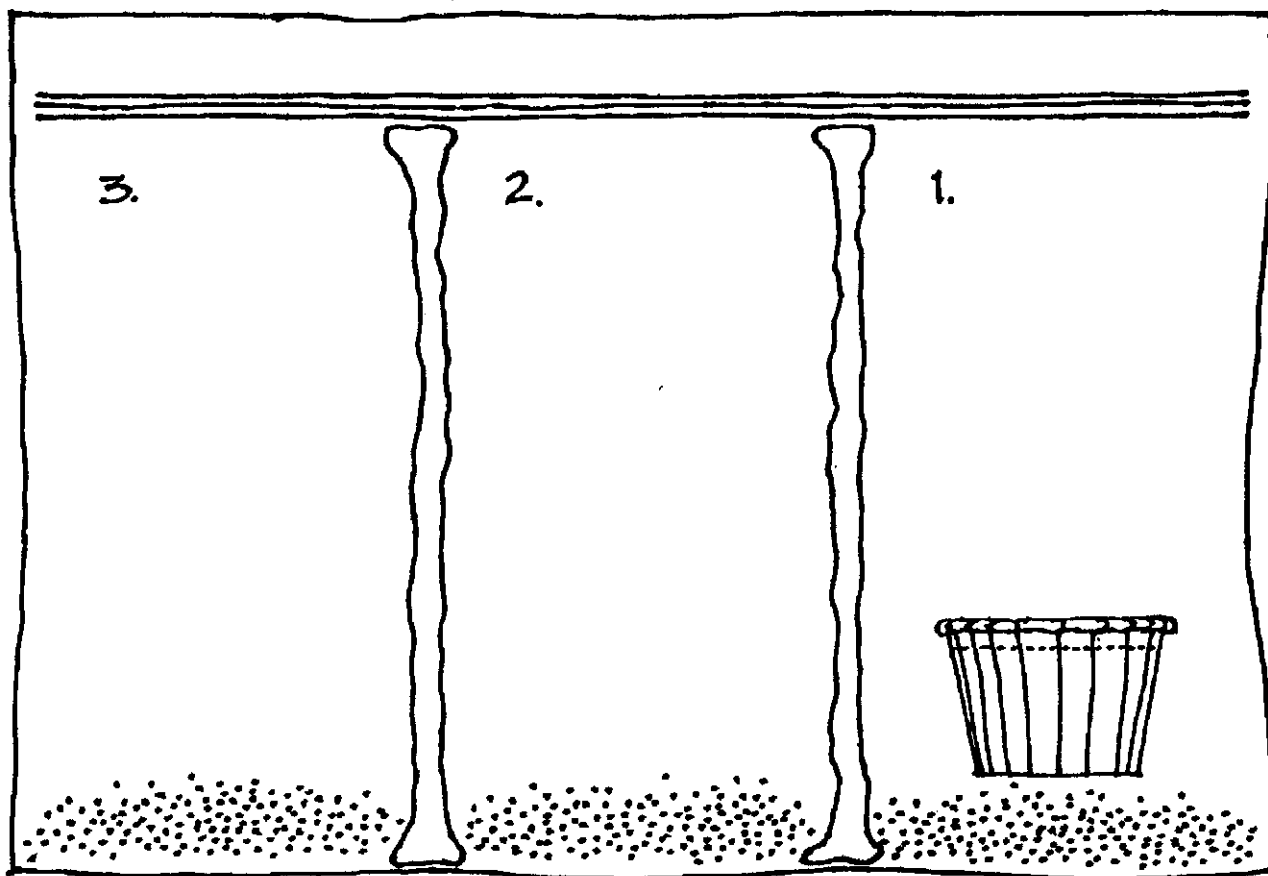
Granular ammonium nitrate
Granular calcium chloride
Plastic bags (*with twist ties*)
Bromothymol blue solution

Baking powder
Paper medicine cups
Thermometers

Procedure:

Prior to class, put one teaspoon of baking powder into enough food bags for each group of students. To half of the bags add a teaspoon of ammonium nitrate. To the remaining bags add a teaspoon of calcium chloride. Tie off each bag with a twist tie. (*Self-sealing bags also work quite well.*)

Tell the students that you are going to give each group a plastic bag with a white powder in it. Randomly distribute the prepared plastic food bags. Ask the students to observe



the powder through the bag. Ask them to determine if there is one or more powders in the bag. Have the students describe the properties of the powder. (*One is silky; the other granular.*) Ask the students to compare the powders in their bag with the powders in the bags of their neighbors. Ask, "Are the powders in your neighbor's bag similar to yours?" (*Yes.*)

Have the students open their bags. Give each group a paper medicine cup containing 2 tablespoons of bromothymol blue solution (BTB). Without spilling the contents, have the students place the cup into the bag. To seal the bag tie off its mouth with the twist tie. When bags are sealed have the students pour the contents of the cup into the powder. Have the students record their observations.

They should observe that the blue liquid turns yellow. Gas bubbles are given off and the bag inflates. Some students will say their bags are cold; others respond that theirs is hot. Tell the students that they have just witnessed a chemical change. Evidence which they observed of a chemical change were: color change, gas production, and a change in temperature. Ask the students if they think the chemical change occurring in all bags is the same. The answer will be "no." When asked to explain their reasoning students will respond that the change cannot be the same if some bags turned cold and others hot. Ask the students what components of the mixture must differ. Since the BTB was the same in all bags, the students will conclude that even if the powders looked the same they must differ. The different powders would result in different reactions.

You may wish to explain that BTB turns yellow in the presence of an acid. In the reaction of BTB and baking powder a gas (CO_2) is produced. The reaction is acidic, causing a change in color of the BTB. The mixing in bags of the BTB solution (*water in the BTB solution is the active ingredient*) and the ammonium nitrate results in an endothermic (cold) reaction. In other bags, the water in the BTB solution and the calcium chloride combine to produce an exothermic (*hot*) reaction.

Further Challenges:

☐ Have students investigate to see who can make the warmest heat pack, or a heat pack that stays warm the longest. Students may try varying the amounts of either the calcium chloride or water.

☐ Have students investigate to see who can make the coldest ice pack. Or the ice pack that stays cold the longest. Students may try varying the amounts of ammonium nitrate or water. The chemical ice packs which can be purchased in a drug store contain ammonium nitrate.

☐ Have students construct a time released ice pack or heat pack. In response to this challenge one student with a bead of white school glue divided a self-sealing plastic food storage bag into three compartments. A teaspoon of ammonium nitrate was placed into each compartment. A medicine cup filled with water was placed into the first compartment. The bag was sealed. The water was emptied into the ammonium nitrate resulting in an endothermic reaction. In the mean time, the water dissolved the bead of the glue separating compartments 1 and 2. The ammonium nitrate in the middle compartment was added to the reaction. The cold was prolonged as the ammonium nitrate in each of the three compartments became part of the reaction.

Safety: As with all chemicals, be sure to read and follow all packaging direction.

SLIME

by Bob Burtch

Focus:

This activity specifically introduces the idea of polymers. Introduce this activity by sharing excerpts from articles in the references "The Plastics Man" and "Slime, Glop, Putty, and Goo: Amazing Fluids That Defy Even Newton."

Challenge:

Students will better understand via guided discovery what constitutes bonding.

Materials and Equipment:

Polyvinyl alcohol	Sodium borate
Hot plate	Paper cups (5 oz.)
Beakers (500 or 1000 ml)	Popsicle sticks
Paper towels	Pencil
Ball point pen	Water base markers
Highlighter pens	Distilled water
Food coloring (or other dye)	

Procedure:

Order polyvinyl alcohol from a science supply house (e.g. Flinn Scientific listed in references). Tell them you are making slime. They know exactly what you need. It comes in powdered form. When mixing use 600 ml water near boiling and slowly add 25 g of polyvinyl alcohol so it does not lump up. You may wish to add fluorescent dye (about 1 ml) to the water. Any food coloring will work. The solution may be made the night before you plan to use it.

Put sodium borate solution in a wash bottle or beaker for easy dispensing. The amount used is 120 ml water to about 5 g. of sodium borate. You may need to heat the water to get it to dissolve. Sodium borate is also sold in grocery stores as a laundry additive called "Boraxo".

Now you're ready to start this activity. Pass out the polyvinyl alcohol solution. Pour to 1" depth in 5 oz cup. Pass out stirrer and paper towel to each student. Have students describe liquid (*don't tell what it is yet*). Have them stir with stick and describe the liquid.

Now tell students it is a solution of polyvinyl alcohol and water. (*Write the words on the chalkboard.*) Now gradually add a small amount of sodium borate solution to the polyvinyl and stir vigorously. It should form into a gel. Remove the slime from the cup and knead it. Pulling the slime slowly creates thin strands. High stress will cause it to break. When rolled into a ball, it bounces. When squeezed, it flattens. When thrown, it may break into pieces.

Slime may last between two days and two weeks depending on how much handling it gets and how clean the hands are. It will eventually mold and should be discarded at this point. There is no real danger in handling it but, as with all chemicals, students should wash hands after use.

Further Challenges

☐ Have students write their names on ordinary white paper. Use water soluble felt-tip marking pen. Have them place slime on their name, lift the slime up and describe the results. (Water soluble inks will be lifted by the slime and students will see the mirror image of what they wrote.)

Safety: As with all chemicals, be sure to read and follow all packaging direction.

References:

Casassa, E. Z., A. M. Sarquis, and C. H. Van Dyke. (1986) "The Gelation of Polyvinyl Alcohol with Borax." *Journal of Chemical Education*.

Flinn Scientific, Inc. Box 231, 917 W. Wilson St., Batavia, IL 60510, (Request Flinn Chemical Catalog and their article about slime. telephone (312) 879-6900.)

Friedal, R. (1984) "The Plastics Man." *Science* 84. November issue p. 49-51.

Killgore, J. (1987) "Slime, Glop, Putty, and Goo: Amazing Fluids That Defy Even Newton." *Scholastic Science World*. p. 23-26, March 23.

Marek, L. (1986) "Slime." *ISTA Spectrum*. p. 21-24, Spring/Summer.

CHAPTER - 12



Human Sun Dials

by Judith McKee



The activity is repeated with the second child's shoe outline and shadow being drawn. The children will step into their shoes and repeat the shadow drawing procedure at various times (*on the hour*) during the day. They should mark the time on the changing shadows.

It is important to emphasize that the sun really isn't moving, though it gives the illusion that it is. Of course, it is the Earth that is moving.

Further Challenge:

☐ Ask students if they can devise other methods and materials to create a sun dial.

Focus:

The oldest way of telling time was done by looking at the location of the sun in the sky. This method was followed by using shadows in various forms of the sundial.

Challenge:

Use children's shadows to tell time.

Materials and Equipment:

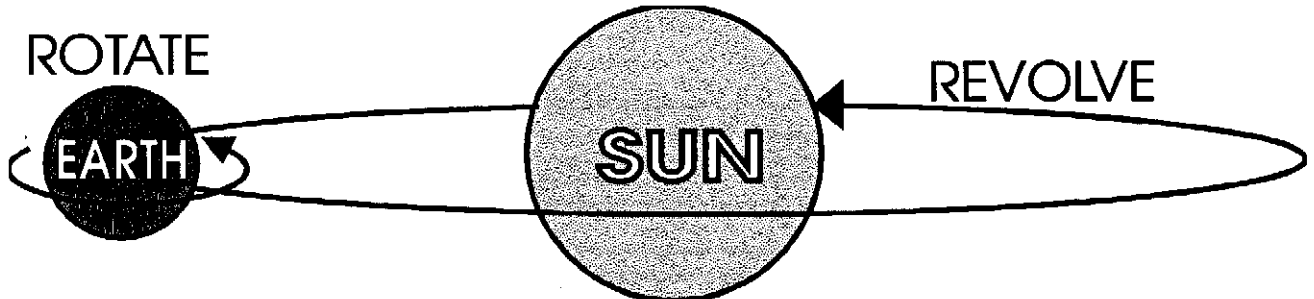
Chalk
Paved outdoor area

Procedure:

Each child will be working with a partner. The children will go to the playground and take turns drawing each other's shadows. The first child stands facing north while the partner traces around the child's shoes and labels this outline with the child's name. Then the shadow is drawn, preferably on the hour. It is best to start early in the day.

Rotate Revolve Game

by Judith McKee



Focus:

Two important motions in the universe are rotation and revolution.

Rotate - to turn around an axis or a center. The earth rotates on its axis.

Revolution - to go around in an orbit. The earth revolves around the sun.

Challenge:

Become familiar with the above terms and know what they mean.

Materials and Equipment:

Large open area

Procedure:

Play this game outside or in a gymnasium. The children circle around one child (*perhaps one who is wearing yellow or orange*) who is to be the sun. They must respond when "the sun" calls "rotate" or "revolve." When the child in the center says, "rotate," the children turn "on their axis" in place. (*Their axis is one foot which they leave in one position while twisting around.*) The center child may call, "revolve," which means that the children orbit the sun. Encourage them to stay an even distance away from the sun so the planet won't get too hot or too cold. The object of the game is for the center child to "catch" one of the others "revolving" when they should "rotate" or vice versa. The

order can be given quickly so as to trick children. Those who are "caught" are out. The last person or persons still "rotating and revolving" at the right time are the winners.

Further Challenges:

☐ A possible variation on this game is to have the student in the center (*the sun*) trade places with the first person caught making the wrong motion. This version of the game is less competitive and involves all students for a longer period of time. The game should be concluded when most students are clear about the distinction between revolution and rotation.

Sizing Up The Sun, Earth And Moon

by Judith McKee

Focus:

It is difficult for children to understand the size relationships of the sun, earth, and moon. Discussions and demonstrations are needed to call attention to how things appear smaller the farther away we are from the objects.

Challenge:

Experience the differences in the size of the sun, earth, and moon by making and using models.

Materials and Equipment:

Beach ball (apx. 2 ft. dia.)	Dried peas
Straight pins	Quarters
Clay	Marking pens
Pictures of earth, sun and moon	String
Tempera paint	

Procedure:

Display the beach ball, the dried pea, and the head of the pin. Explain that if the sun were the beach ball, earth would be the size of the pea and the moon would be the size of the head of the pin. Explain that a million earths could fit inside the sun.

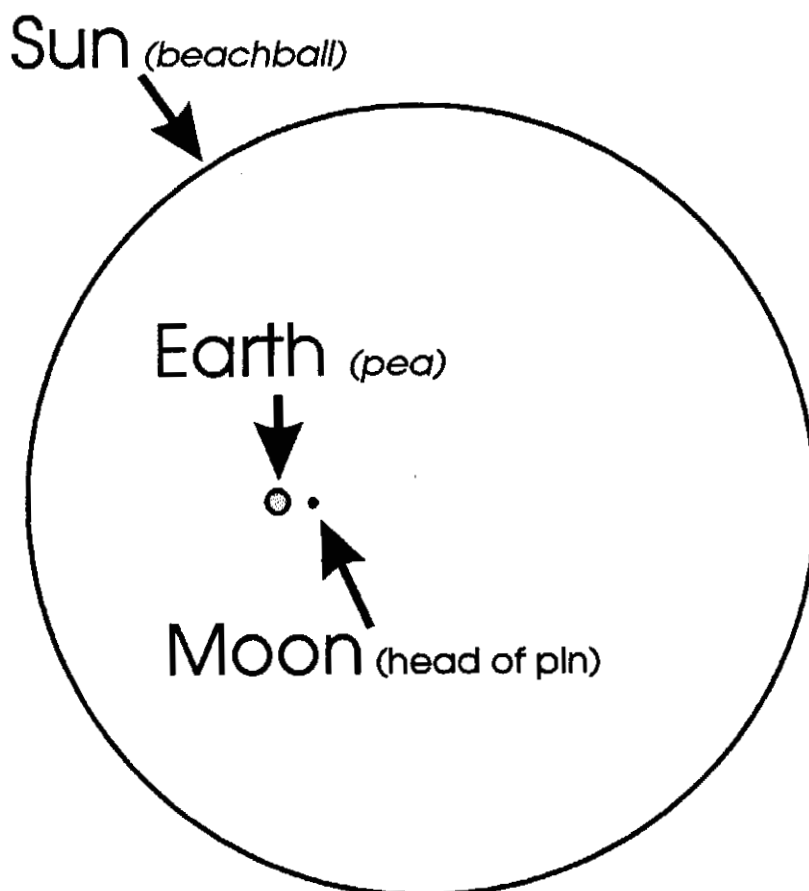
Hold up the quarter for all to see. Walk away continuing to hold up the quarter while the children watch the quarter appear to get smaller. Discuss their experiences with perspective.

Give each child a large fistful of clay. Have them make seven balls of clay of approximately equal size. When finished, put six of the balls together to form one big sphere. (*This sphere represents the earth.*) The remaining ball is a model of the moon as compared to the earth. Then continents, the equator, etc. can be etched into the earth while craters can

be put on the moon. Photographs should be available for viewing. Later after the clay dries, the spheres can be colored with marking pens or tempera paint to look like the photographs. Remind students to include the earth's polar caps and its swirls of atmosphere.

Further Challenges:

□ Ask the children to guess how far the moon would be from earth using their clay models. They can put these on their desks. Then, using a piece of string, demonstrate how to measure the diameter of the earth. The moon is 30 of these diameters away from earth. The children can each do this using their own models and a length of string.



Simple Solar System Model

by Judith McKee

Focus:

It is easy for the children to remember the names of the planets and their order away from the sun by repeating this: My Very Educated Mother Just Served Us Pink Noodles. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Pluto and Neptune are the planets in their current order away from the sun. The traditional mnemonic device reads "Many Very Earnest Men Just Showed Us Nine Planets." However, because of Pluto's eccentric orbit, it is occasionally closer to the sun than Neptune. This is the case now, as this sourcebook is being published.

Challenge:

The idea of "astronomical unit" will be introduced and a model of the members of the solar system with their relative distances away from the sun will be made.

Materials and Equipment:

Rulers
Adding machine tape
Crayons or markers
Pencils

Procedure:

Introduce the term "astronomical unit" (*the distance between Earth and the sun in any model*). Give each child a length of adding machine tape at least 4 meters long. Tell children to use 10 cm as their astronomical unit, though any size will work if you have enough adding machine tape. Then they are to make their model of the solar system by marking off where the other planets are to be on the tape. All the planets should be spaced as shown below. Each length is measured from the sun.

Small drawings of the planets can be made. The planets are rarely aligned like this. Usually they are scattered in various places on their elliptical orbits which, from outside the solar system would look like disks. Pluto's orbit, however, is a peculiar one because it deviates greatly from the others.

Further Challenges:

☐ Repeat the activity but use one meter as the astronomical unit. String can be substituted for the adding machine paper. Names of the planets could be attached at the appropriate places. To give the children an idea of the size

Planet	Astronomical Units	Centimeters at 10 cm = 1 A.U.	Millions of Kilometers	Millions of Miles
Mercury	.4	4	58	36
Venus	.7	7	108	67
Earth	1.0	10	150	93
Mars	1.5	15	225	140
Asteroid Belt	2.3	23	350	217
Jupiter	5.1	51	770	480
Saturn	9.6	96	1430	890
Uranus	19.4	194	2900	1800
Neptune	30.1	301	4500	2800
Pluto*	39.8	398	6000	3700

**Note: The average distance from Pluto to the sun is being used here.*

	Earth Diameters Diameters	Diameter in Kilometers	Diameter in Miles
Sun	109	1,400,000	864,000
Mercury	0.4	4,800	2,900
Venus	0.9	12,200	7,530
Earth	1	12,600	7,900
Mars	0.5	6,700	4,200
Jupiter	11.0	139,000	86,800
Saturn	9.0	115,000	71,500
Uranus	3.7	47,000	29,400
Neptune	3.5	45,000	28,000
Pluto	0.2	2,900	1,800

relationships of the planets, supply them with the information in the chart above. It shows the approximate size of the sun and planets in relation to the size of the Earth.

☐ Challenge students to create a model of the solar system that is accurate in scale for both size and distance.

Hint: With a scale of 1 A.U. = 10 meters, the sun will be approximately 92 mm in diameter. This is quite small considering Pluto will be nearly 400 meters away. Even on this large scale, the planets will be very small. (i.e. Earth is less than 1 mm.) Students can calculate this size from the information given in the charts above. For your convenience, these related sizes have been calculated and are listed below. (Sun = 92 mm. Mercury = 0.3 mm. Venus = 0.8 mm. Earth = 0.8 mm. Mars = .4 mm. Jupiter = 9.3 mm. Saturn = 7.6 mm. Uranus = 3.1 mm. Neptune = 3.0 mm. Pluto = 0.3 mm.)

Scale Model Solar System

by Mark R. Malone

Focus:

It is very difficult to create a true scale model of the solar system that is accurate both in terms of planet size and distance. By the time the distances are small enough to fit in the classroom or school yard, the planet sizes are almost too small to be meaningful. This model uses the sun and planets on a larger scale and deals with placement in terms of distances students could easily travel in a car or bus.

Challenge:

Change students' conception of the relative size of the solar system by creating a true scale model.

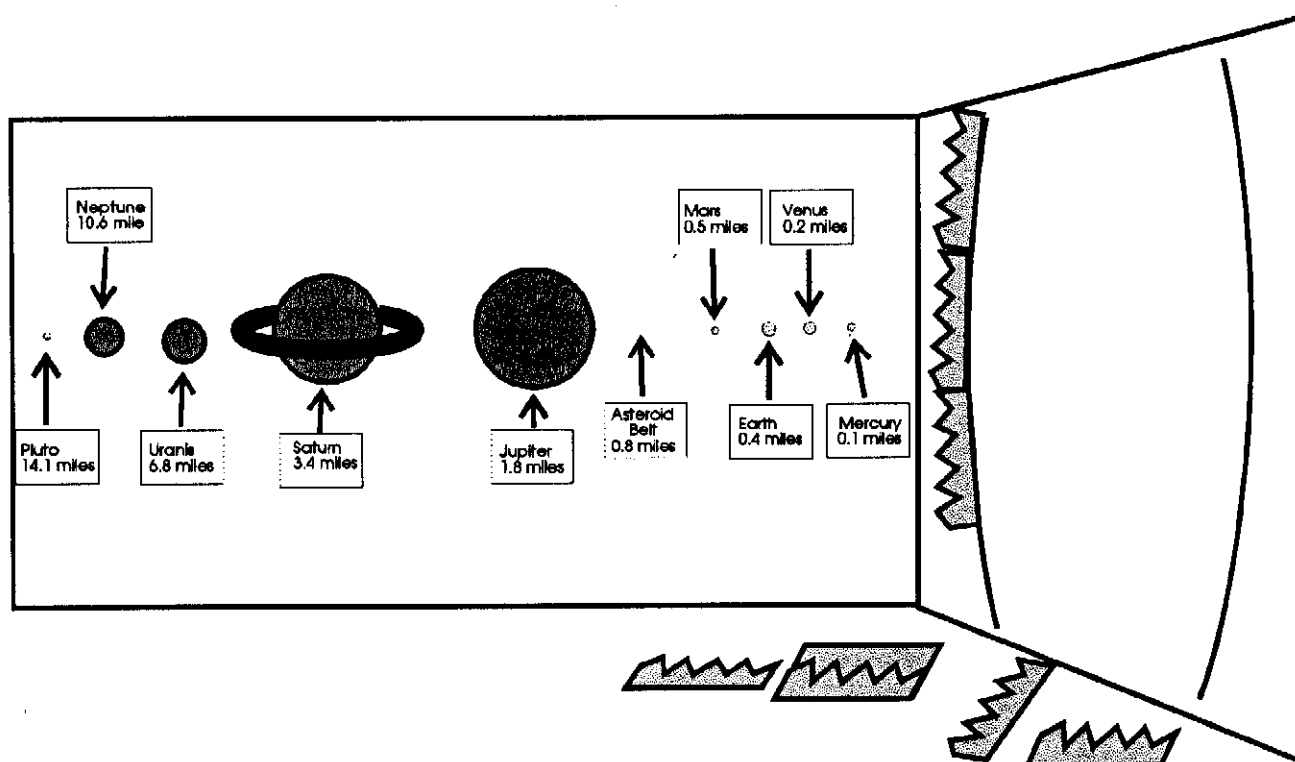
Materials and Equipment:

Posterboard	String
Tape	Scissors
Drawing Compass	Pencils
Tempera Paints	Construction paper

Procedures:

Use a compass and scissors to make planets to size from posterboard. Actual scale sizes are given in metric and English measurements in tables on the next page. You may wish to choose the color and patterns based on library reference sources. A compass will not be large enough to make the larger planets such as Jupiter and Saturn. For those you will need to tie a string to a pencil and cut the string to the length of the radius of the required circle. Tape or hold the free end of the string in the center of the posterboard and trace the circle with the pencil. After construction you may wish to tape planets in order on the wall. Under each planet, place a card showing how far away in miles or kilometers the planet would need to be placed to be a true scale model.

To create a scale model of the sun, tie a long piece of string to a piece of chalk. Cut the string to approximately 9 feet (3.5 meters) in length. Hold or tape the string in the center



Scale for Sun and Planets with a 2 in. Earth (ENGLISH MEASUREMENT)

	Relative Size	Relative Distance
Sun	208" (18.2')	
Mercury	3/4 inch	0.1 mile
Venus	1 3/4 inch	0.3 mile
Earth	2 inches	0.4 mile
Mars	1 inch	0.5 miles
Asteroid Belt		0.8 miles
Jupiter	22 inches	1.8 miles
Saturn	18 inches	3.4 miles
Uranus	7 3/8 inches	6.8 miles
Neptune	7 inches	10.6 miles
Pluto	3/8 inch	14.1 miles

where planets should be placed to be the correct distance from school.

☐ Take along the planet models on a field trip. As the bus moves away from the school, monitor how many miles you have traveled. When you get to key miles, announce to students which planets would need to be dropped off to make a true scale model of the solar system.

of the wall adjacent to the planets. Holding the chalk pull the string taut and draw a chalk outline floor to ceiling on both sides of the string. You have now created a partial circle outline of an 18 foot model sun. You may wish to create the corona of the sun by cutting yellow construction paper in half lengthwise with a jagged line. These jagged outlines can be taped along the chalk outline as shown below.

Further Challenges:

☐ Have small groups of students research factual information about the sun or a particular of the planet. They should report back to the class about their planet.

☐ Have small groups of students research mythology related to the name of a planet. They should report back to the class about the nature and origins of these mythological characters.

☐ Have students work in small groups to create models of the planets to scale out of paper mache'. These models might be displayed by hanging them from the ceiling in the classroom or hallway. These could be displayed with information about distance or other facts about the planets.

☐ Have students work with a map of the local community. Using the scale of miles on the map and a compass, they should identify landmarks

Scale for Sun and Planets with a 6.4 cm Earth (METRIC MEASUREMENT)

	Relative Size	Relative Distance
Sun	694.0 cm. (7 m.)	
Mercury	2.5 cm.	0.3 km.
Venus	5.7 cm.	0.5 km.
Earth	6.4 cm.	0.7 km.
Mars	3.2 cm.	1.1 km.
Asteroid Belt		1.7 km.
Jupiter	70.0 cm.	3.8 km.
Saturn	57.3 cm.	7.0 km.
Uranus	23.5 cm.	14.3 km.
Neptune	22.3 cm.	22.3 km.
Pluto	1.3 cm.	29.7 km.

Moon Mobile

by Ruth M. Rund

Focus:

The purpose of this lesson is to familiarize the students with the different phases of the moon, the sequence of the phases, and time of moonrise and moonset. This lesson can be adapted for various ages.

Materials and Equipment:

Pieces of string (*apx. 15 cm long*)
Patterns of moon phases
Hole punch

Wire coat hanger
Construction paper
Markers or crayons

Challenge:

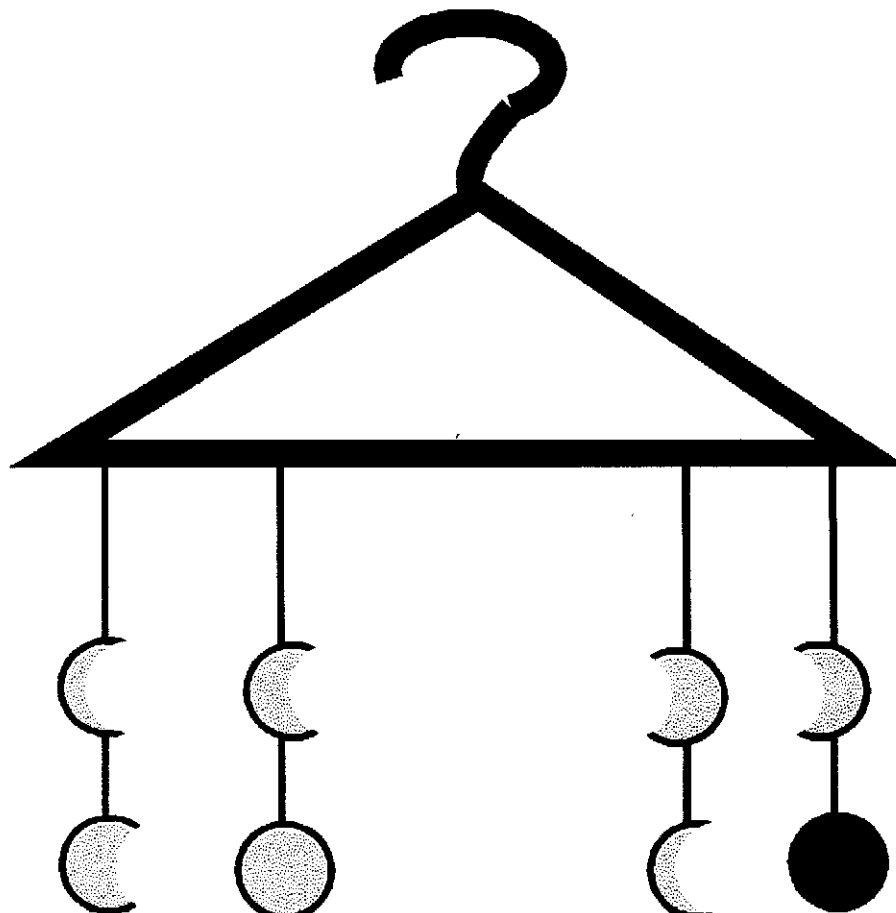
Demonstrate the reflected light of the moon and its phases by using a flashlight or light source, an orange, and a golf ball. Discuss the various phases that are formed.

Procedure:

Have students trace the patterns of the phases of the moon onto the construction paper. Punch a hole at the top of each phase. Tie the string to the phase and then to the hanger. Students then can see the phases beginning with new moon, waxing crescent, first quarter, full moon, waning crescent, and last quarter.

Further Challenges:

- ☐ Add the gibbous (*three quarters full*) phases.
- ☐ Add the moonrise and moonset for each phase.
- ☐ Have the students chart the moon phases for one month.
- ☐ Have students chart the moon's position for one month.



A Cupful Of Stars

by Ruth M. Rund

Focus:

Children can become aware of the constellation patterns in the night sky by recognizing them in different ways. The Big and Little Dipper, Cassiopeia, and Orion are the easiest constellations for children to find.

Challenge:

Have a student recognize a constellation by its pattern.
Have the student make the pattern and identify it.

Materials and Equipment:

Styrofoam cups	Pencils
Copy of the constellation patterns	Flashlight

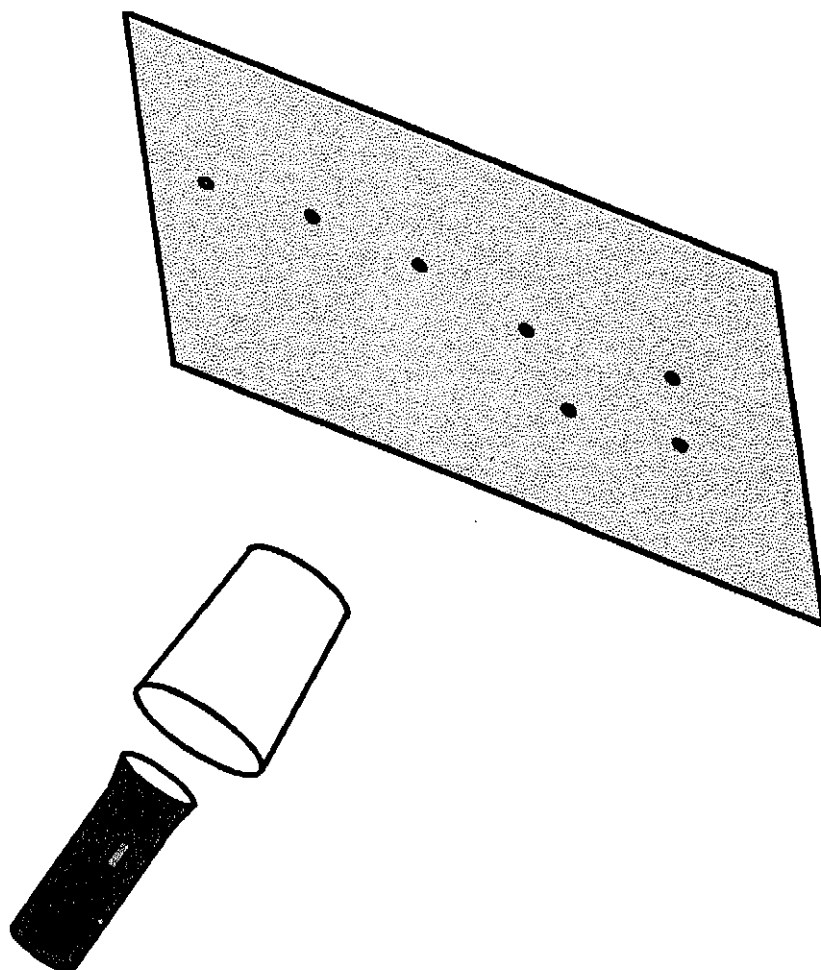
Procedure:

Give each student a styrofoam cup. Have students use a pencil to mark where stars will be placed. The students will then punch small holes through in the bottom of the cup.

Have the students shine the flashlight through the cup in a dark place. The light should project the constellations they have created on to the wall

Further Challenges:

☐ Set up a learning center with the materials used above. Students should project constellations onto a piece of white cardboard and practice identifying them.



How Big Is That Sun?

by Tom Graika

Focus:

The sun is a long way from Earth. Yet when viewed from Earth it appears to be about the same size as the much closer moon. In fact, when a solar eclipse occurs, the moon just about blocks out the entire sun. Using very simple equipment, it is possible to make an estimation of the size of the sun. For this activity an average distance to the sun of 93 million miles will be used.

Challenge:

How can the size of the sun be measured from Earth?

Materials and Equipment:

Index cards	Meterstick
Millimeter ruler	Pin
Paper	

Procedure:

Cut a hole near the base of each of the index cards so that the cards could be slipped onto the meterstick as shown on the diagram. On one of the cards punch a small hole with a pin. On the other card mark out a series of lines one millimeter apart.

Slip the cards onto the meterstick with the millimeter scale facing the card with the pinhole. Go outside on a sunny day and use this equipment to measure the size of the sun. Instruct students not to look directly at the sun. Working with partners will make the task easier. Work with your back to the sun. Point the end of the meterstick that has the card with the pinhole toward the sun. When the light passes through the pinhole it will form an image of the sun on the other card. This card will be in the shadow of the pinhole card for easy viewing of the image. Slide the cards back and forth until an image three millimeters in diameter is formed. Measure the distance in millimeters between the cards (*approximately 323 mm*).

To calculate the size of the sun the simple ratios above may be used. The sun's size can be calculated in

FORMULAS TO ESTIMATE THE SIZE OF THE SUN

$$\frac{\text{diameter of the sun}}{\text{distance to sun}} = \frac{\text{diameter of image}}{\text{distance to image}}$$

$$\frac{\text{diameter of the sun (miles)}}{93,000,000 \text{ miles}} = \frac{3 \text{ millimeters}}{323 \text{ millimeters}}$$

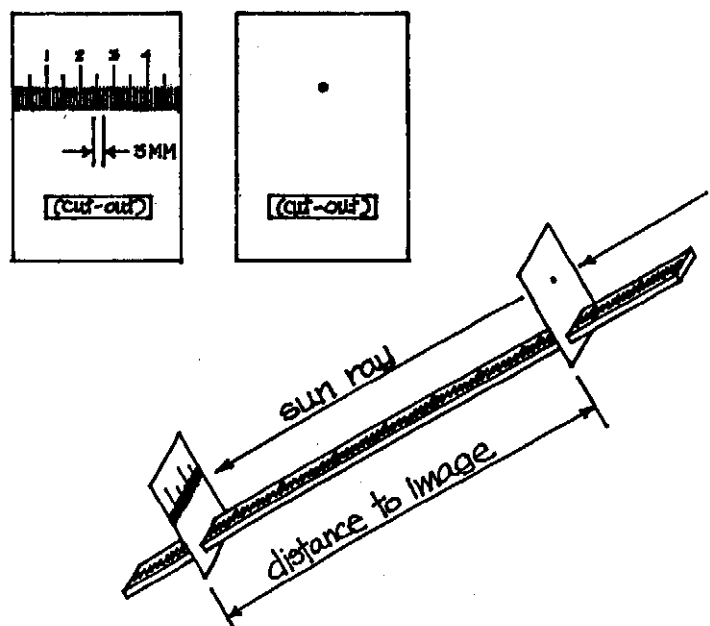
or

$$\frac{\text{diameter of the sun (kilometers)}}{150,000,000 \text{ kilometers}} = \frac{3 \text{ millimeters}}{323 \text{ millimeters}}$$

either miles or kilometers. Cross multiplying and dividing by the distance between the cards will produce your estimate of the diameter of the sun. Compare your answer with one given in the previous activity; *Simple Solar System Model*. How close was your estimate?

Further Challenges:

- ☐ Repeat the investigation using different sized images.
- ☐ Take an average of all your findings. Does this come closer to the actual diameter of the sun?
- ☐ Find out how scientists estimate the size of space objects.



Finding Constellations

by Tom Graika

Focus:

The stars in the sky seem to be scattered in an endless array. Sometimes by connecting the stars with imaginary lines we can see patterns or even the shapes of familiar objects. The Big Dipper is a good example. Ancient peoples used the patterns in the sky to tell stories. They imagined hunters, animals, and many other objects in the sky to illustrate their stories.

Challenge:

How many different "constellations" can be found in the pattern of stars in the illustration below?

Materials and Equipment:

Illustration below (or similar)

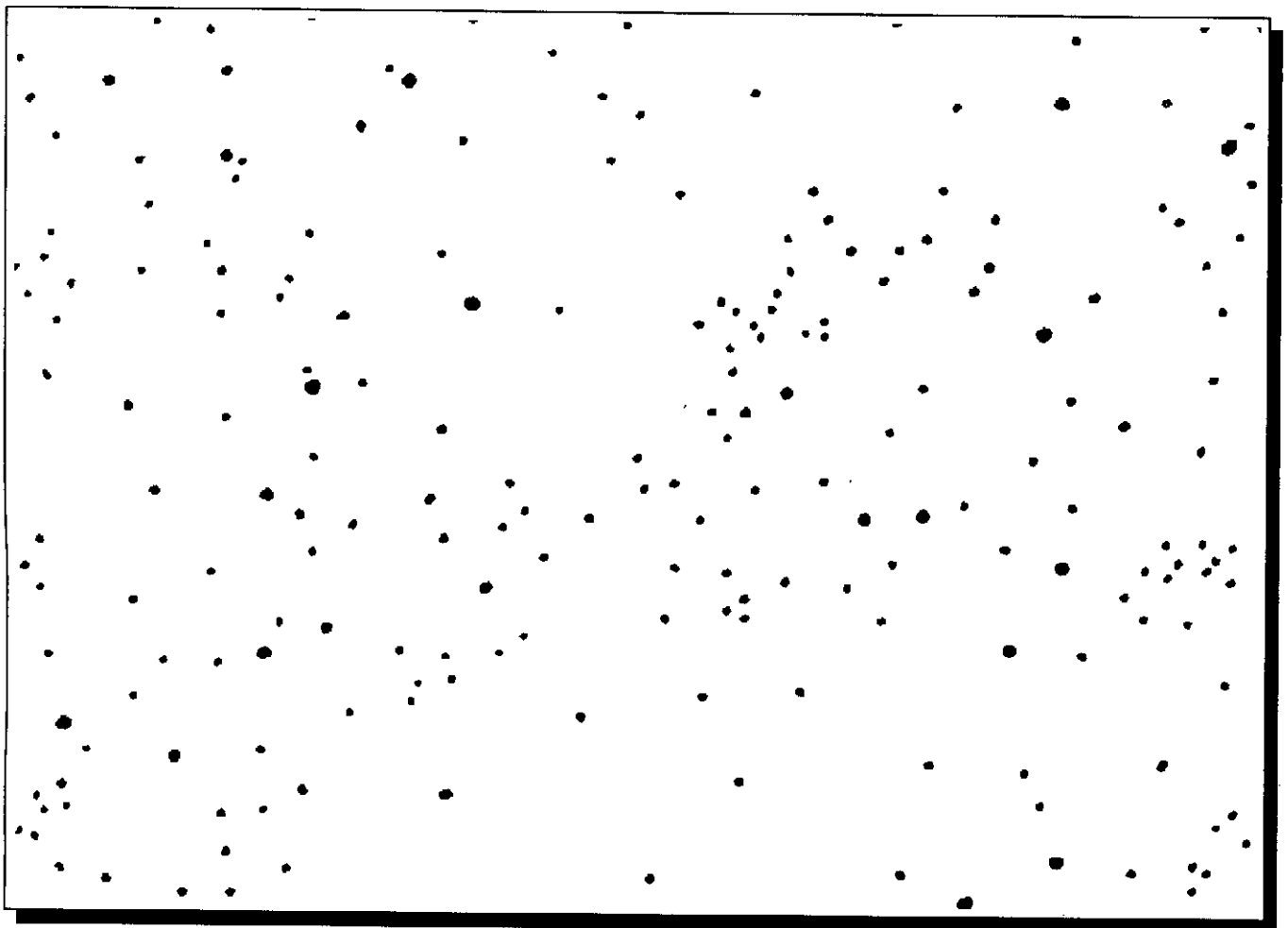
Pencil

Procedure:

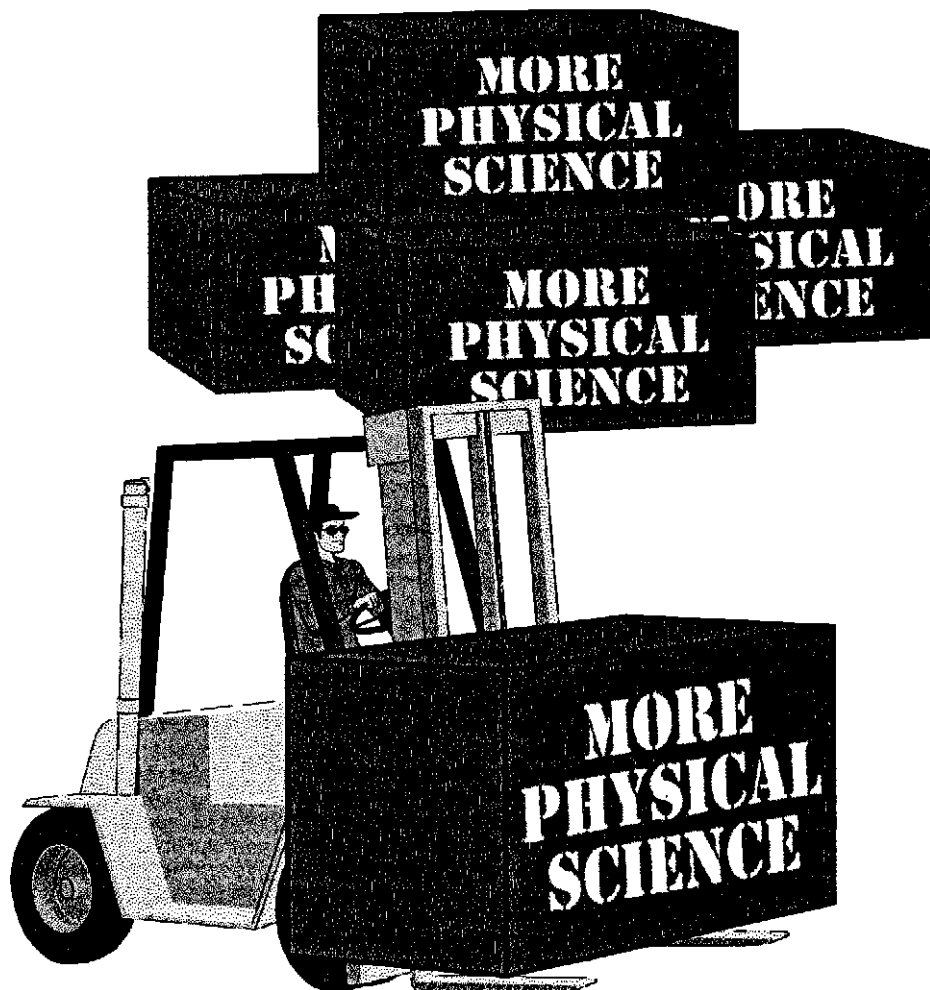
Give each student a copy of a scattergram of dots similar to the one illustrated. Ask the students to find different "constellations" on their scattergram of "stars".

Further Challenges:

- ☐ Have students make up a story using some of the "constellations" they found.
- ☐ Have students find out about some of the myths and stories associated with constellations in the sky.



CHAPTER - 13

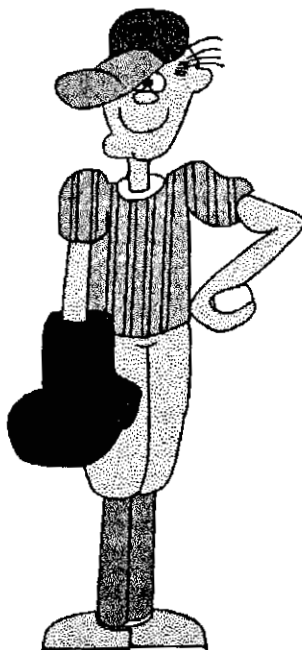


Teach Physics Through Sports And Games

by Charles Nease

Focus:

Concepts such as force, power, and momentum make sense to elementary students when they see them operating in their favorite activities. For example, a discussion of different types of forces becomes meaningful when it is preceded by a "lab" on the softball field. Pushes and pulls can be exerted by our bodies or with sports equipment. Friction, the resistance between two objects moving against each other, makes pushing things more difficult, but it also allows us to run, grip a bat, and catch a pop fly. Elastic force causes a distorted object, such as a hit ball, to return to its original shape



Why didn't you slide all the way across the playground and crash into the fence? *(Friction with the ground slowed me down.)*

What happened when the ball hit your glove? *(The force of the moving ball pushed my glove back, and the force of my hand made the ball slow down and stop.)*

Why hasn't the ball become pancake-shaped from the pounding it has taken? *(The elastic force keeps returning it to its original shape.)*

What made you slip and fall when rounding first base? *(There wasn't enough friction between the wet grass and my shoe to resist the force of my leg.)*

Challenge:

Identify and explain the forces at work during selected moments of a class softball game.

Materials and Equipment:

Bat	Softball
Bases	Gloves

Procedure:

Use the ball playing field as a "lab" for discussing the forces involved in playing baseball or softball. At appropriate times suspend play and ask questions like those listed below. You may wish to define *force* as "an action that can cause an object to change speeds" (*accelerate or decelerate*). Elicit examples of forces from your students. Hopefully some of these will be sports related. You may wish to discuss two categories of forces, *contact forces* (pushes, pulls friction, elastic force) and *distance forces* (gravity, magnetism, electrical force, nuclear force).

Example questions:

Why didn't the ball keep going into outer space? *(It didn't have enough force to overcome the force of gravity and friction against air particles.)*

Further Challenges:

The activity described above is only a beginning; it is only one of many possibilities. Use the references below to develop additional lessons on power, momentum, trajectories, etc.

Have students apply what they have learned to demonstrate physics principles associated with rope jumping, Frisbee, soccer, and other games.

References:

Brancazio, Peter J. (1984) *Sport Science: Physical Laws and Optimum Performance*. NY: Simon and Schuster.

Epstein, L.C. & P.G. Hewitt. (1981) *Thinking Physics: Questions with Conceptual Explanations*. San Francisco: Insight Press.

Schrier, E.W. and W.F. Allman. (1984) *Newton at the Bat: The Science of Sports*. NY: Charles Scribner's Sons.

Cartoons To Enrich Science

by Charles Nease

Focus:

Cartoons provide an excellent medium for relating or reinforcement of science concepts and skills. Some cartoons provide a humorous bent on science concepts or hot issues. Others provide students with practice in skills of observation, inference, and prediction. In the cartoon below one can only understand the humor based on what is observed and what must be inferred. Knowing the difference between an observation and an inference is an important distinction in science and problem solving.

Challenge:

What scientific concepts can you discover in these cartoons? What science skills can must you apply to interpret the humor of a cartoon?

Materials and Equipment:

Cartoons from books, magazines, and other sources
Slides or transparencies of cartoons
Camera with copy stand or a suitable copy machine
Slide projector or overhead projector

Procedure:

Select twenty to thirty cartoons related to the concepts or skills your class has studied. Newspapers, magazines, and books such as those listed at the end of this article are good sources. You may wish to concentrate on one or two areas from your curriculum, or you may prefer to choose a wide variety for a general review.

Cartoons may be mounted or laminated to be used in a center designed for individuals or small groups. However, whole class viewing is much more enjoyable and allows students to share more ideas through teacher directed discussions. Cartoons can easily be copied on to overhead transparencies. The goal is to identify and explain as many science related concepts or apply as many science skills as possible for each cartoon.

Note: Some cartoons will contain sexually oriented, ethnic, or other objectionable content. You may wish to scrutinize these sources before sharing them with your students.

Further Challenges:

- ☐ Have students search for science related cartoons and bring them to class to share.
- ☐ Have students create their own cartoons to illustrate the content and processes they have studied.

References:

- Chast, R. (1984) *Parallel Universes*. NY: Harper & Row.
- Harris, S. (1977) *What's So Funny About Science?* Los Altos, CA: William Kaufmann, Inc.
- Larson, G. (1984) *The Far Side Gallery*. Kansas City: Andrews, McMeel Parker.
- Mueller, P.S. (1986) *The Spread of Terror*. Chicago: Bonus Books.



How Many Milliliters In A Gallon?

by Michael J. Demchik

Focus:

Estimating the number of milliliters in a gallon or similar type of estimation activity takes skill and practice.

Challenge:

How many milliliters are there in a gallon?

Materials and Equipment:

Gallon jug Water
Beakers

Procedure:

Fill a gallon jug to the neck with water. This usually is the exact point where one gallon is found. Ask students individually or in small groups to guess the number of milliliters in a gallon after having shown them what one milliliter looks like. Ask them to write down their

estimate.. Remove 500 ml of water from the jug and stand the container next to the gallon jug. Ask the students to make another estimate of the number of milliliters in the gallon. You may wish to repeat this process until the jug is empty. After each repetition students should list the value next to each of the previous estimates.. Have the students compare their earlier estimates to their later ones. Determine what factors affect the data they collected.

Further Challenges:

- ☐ Ask students to estimate and measure the number of milliliters in various other containers such as: a bucket, a flower pot, a wastebasket, a bath tub, a sink, a coffee cup, etc.
- ☐ Do similar estimates with length, weight, etc.
- ☐ Have students devise various means of estimating the same quantities.



Measuring Tall Things

by Michael J. Demchik

Focus:

Indirect measurements of height can be accomplished with an instrument known as a hypsometer. The hypsometer employs the principle that when a right triangle has two 45° angles, it is possible to make an indirect measurement of height. The instrument works only in the manner to be described when the angles are 45°, 45°, and 90°.

Challenge:

What is the height of the tree to be used in this activity? What methods can be used to determine the height of tall objects? How is a hypsometer used? Are there any instruments that are used to measure height in the same fashion as this homemade hypsometer?

Materials and Equipment:

Scissors
Cardboard
Meter stick or measuring tape

Procedure:

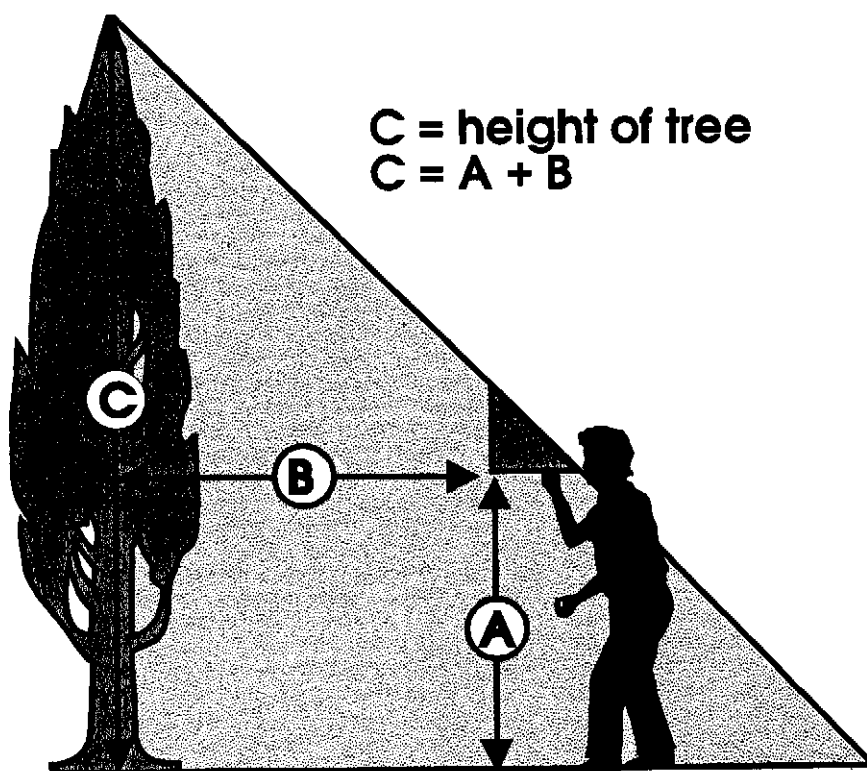
Construct a hypsometer by cutting a square piece of cardboard along the diagonal such that, when the cut is complete, the angles formed are 45°, 45°, and 90°. Sight a distant object by placing the hypsometer to one's eye and sighting along the diagonal to the top of that object. Have another student level the hypsometer until it is parallel with the ground. Move either backward or forward until the diagonal and the top of the object are in line. Measure the height from the ground to the eye and add this distance to the distance found when one measures from the sighting point to the object. This distance is the height of the object.

Further Challenges:

☐ Measure the actual distance of the object being measured and compare it to the distance found with the hypsometer. The percentage of error is found by using the formula below.

$$\frac{\text{Hypsometer height} - \text{Actual height}}{\text{Actual height}} \times 100 = \text{percent error}$$

☐ Try various sized hypsometers and determine which has the smallest percentage error.



Measuring Wide Things

by Michael J. Demchik

Focus:

This activity should be performed after the activity called "Measuring Tall Things". The width of a road, river or ball field can be determined with the hypsometer. The operation is the same as when measuring height. All that is needed is a reference point.

Challenge:

How are the measurements of height and width related when the hypsometer is used?

Materials and Equipment:

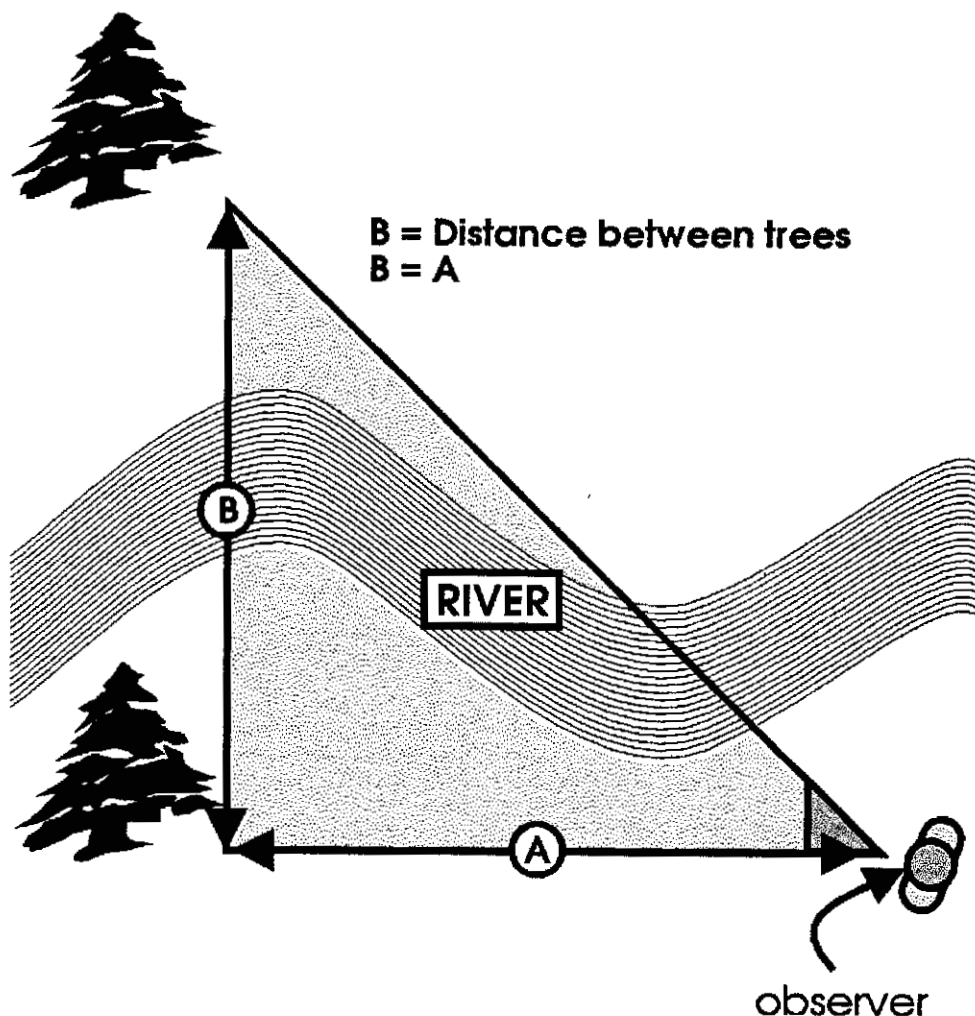
Cardboard hypsometer (*see previous activity*)

Procedure:

Place the cardboard hypsometer parallel with the ground. Find a reference point such as a tree or a rock and sight along the diagonal until the line of sight is in line with the reference object. Mark this sighting point on the ground. Walk to a point perpendicular to the reference point and sight along the edge of the hypsometer from the new position. Mark it. Measure the distance between the two points. This should be the distance across the road or the river.

Further Challenge:

- ☐ Compare the results with different sized hypsometers.



Propelling Students Into Variables

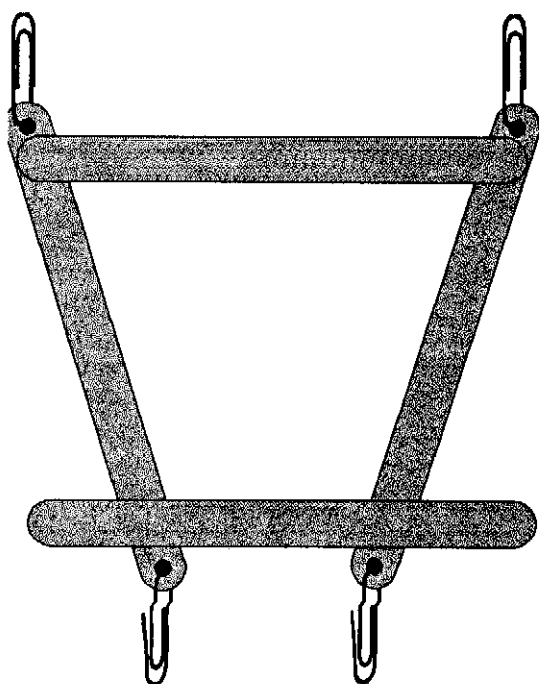
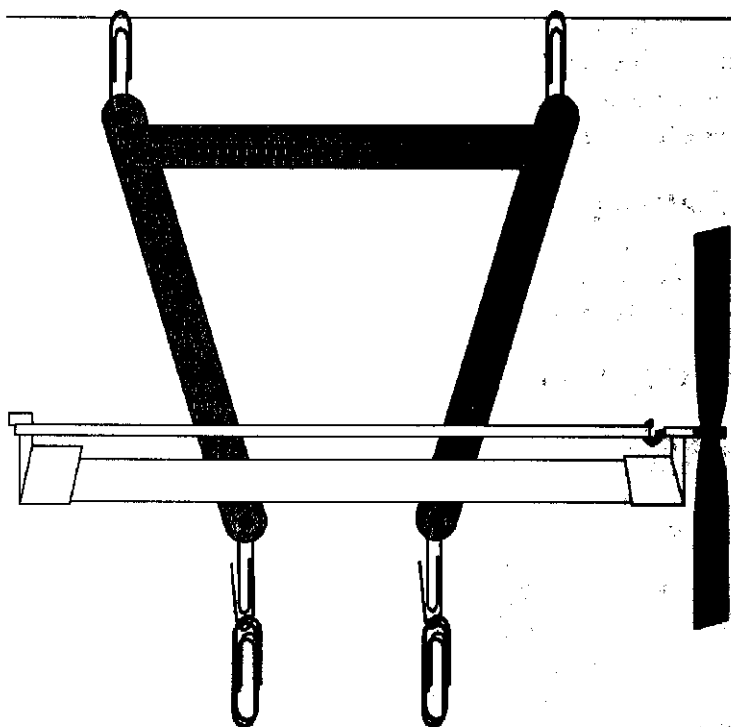
by Mark R. Malone

Focus:

Propeller driven aircraft have been with us for generations. It was a simple propeller toy that, to some degree, inspired the Wright Brothers as children to become fascinated with flight and ultimately design the first heavier than air, powered, flying machine nearly a hundred years ago. This activity modifies a simple toy often found in hobby shops, grocery stores, and convenience stores, the wind-up balsa wood toy airplane.

The device you will construct in this activity could be used to explore a variety of concepts and skills. As part of an energy unit it could be used to investigate energy concepts:

- *To increase the total output of a system, the amount of energy applied to the system must be increased.*
- *If the total amount of energy in a system is held constant, increasing the mass can make the system less efficient.*
- *Energy in a mechanical system is transferred from a source to the components of the system. Each transfer involves an energy supply and an energy receiver.*

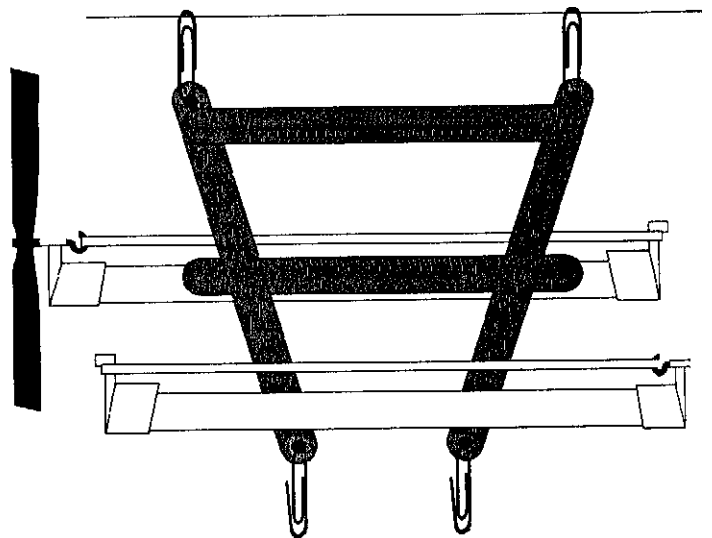
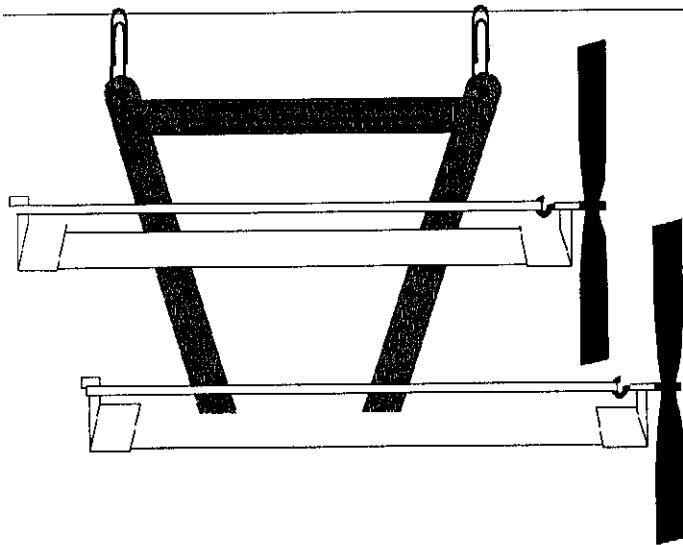


The device may also be used to introduce or practice a variety of science process skills such as:

- *Identifying and controlling variables.*
- *Observing, measuring, and recording data.*
- *Graphing and interpreting data.*
- *Predicting and inferring*
- *Applying energy transfer concepts to real world situations.*

Materials:

wind-up balsa wood toy airplanes
craft sticks
wood glue
fishing line - 14 LB (6 kg) test
paper clips (#1 - small)
masking tape
measuring tapes
graph paper



Construction:

To construct the propeller / platform system (*PPS*) you will need a wind-up balsa wood airplane for each group of students. Discard the wings, tail, and rudder. You will only be using the propellers, body shafts, and back hooks.

The body of the PPS is constructed of four craft sticks and four paper clips. Drill holes approximately 3 mm ($\frac{1}{8}$ in) diameter in the end of two craft sticks as shown. Use wood glue to attach the four craft as shown above. Attach four paper clips through the drilled holes. The bottom paper clips should be spread out to serve as hangars for additional paper clips. Attach the airplane body to the platform using masking tape as shown in below.

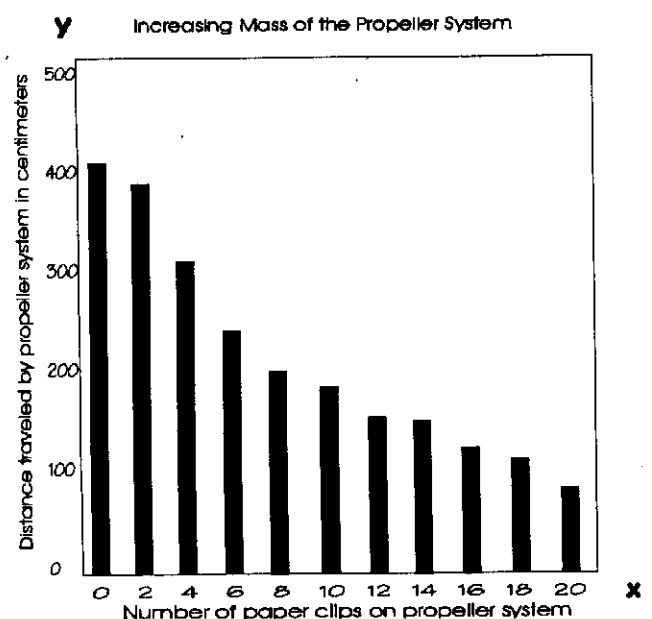
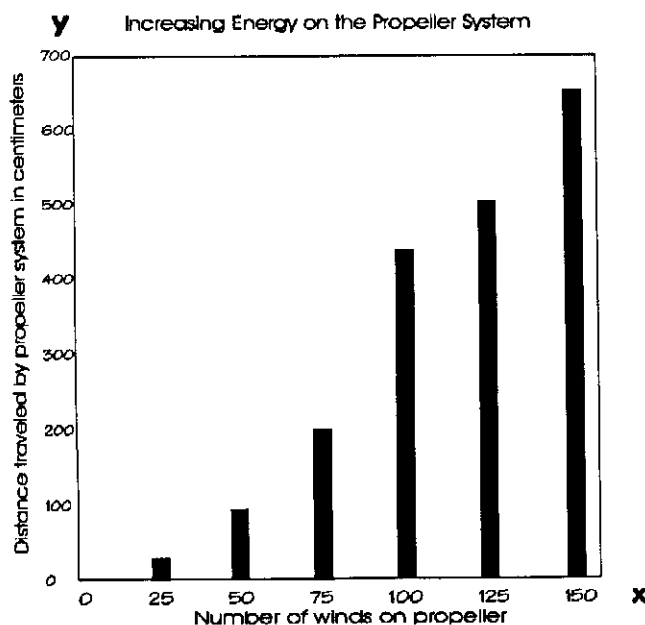
It will be necessary to string a length of fishing line approximately 7 meters (24 ft) in length for each group. The

fishing lines need to be tied off very taut and level. Use the top paper clips of the PPS to fasten the platform to the fishing line (*top right of previous page*).

Procedures:

Start by simply demonstrating how the propeller / platform system (*PPS*) can move along the string. Simply wind up the propeller 75 to 100 winds and let go. Next ask students to brainstorm what factors might effect how far the PPS will travel along the string. Students will likely consider the effects of increasing the winds on the propeller, increasing the mass of the PPS, and otherwise modifying the device.

Have them start by exploring the effect of increasing winds on the propeller. They should measure the distance the PPS travels with an increasing number of winds (e.g. 25, 50, 75,



100, 125, 150). You may wish to have them do multiple trials with each number of winds to determine and average distance traveled. The information should be compiled on a data sheet and graphed. (*A sample graph of typical data is shown on the previous page.*)

These procedures can be repeated for increases in mass on the PPS. Increasing the mass of the system in increments equivalent to the weight of two paper clips is a convenient interval. (*A sample of typical data for increases in mass is shown on the previous page.*)

There are also many possible modifications of the PPS design that students may wish to explore. Two such modifications using two propellers are pictured on this page. Note that the first design shows propellers working in tandem while the second shows the propellers working in opposition. When the propellers are working in opposition, it is interesting to vary the number of winds on the opposing propellers independently. For example place 50 winds on the left propeller and 100 winds on the right.

You may wish to conclude this lesson by leading students through a discussion of how this activity relates to energy use in the real world. Generally vehicles that are heavier get fewer miles per gallon. If you want to go further faster, you will consume more energy than going a short distance slowly. This could be related to automobiles, airplanes, and other vehicles.

Interesting Design Flaw:

My first design for this activity appeared to be a dismal failure. Instead of using paper clips to attach the device to the fishing line I chose to use soda straws (*below*). The system worked for a few trials and then ceased to move well and in

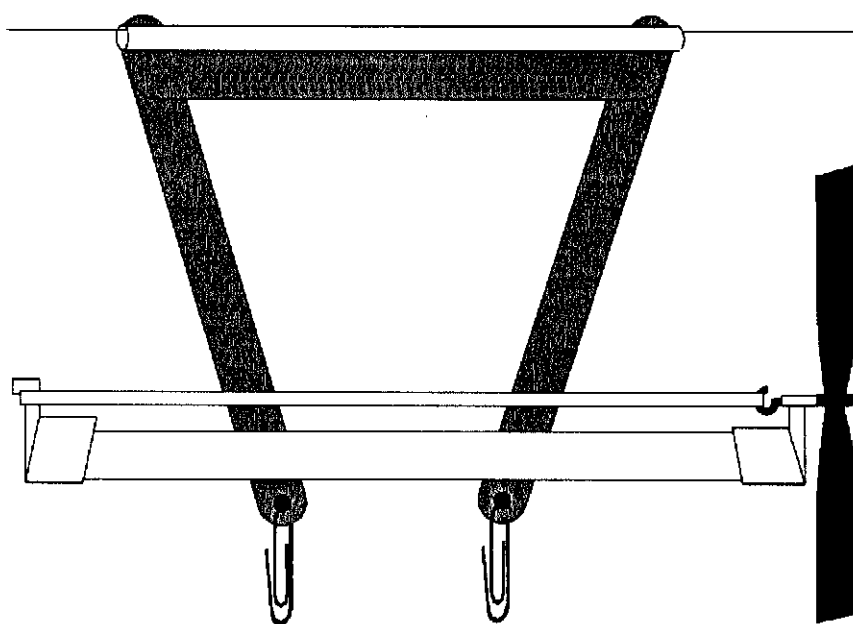
some cases would not move at all. My graduate students puzzled over the problem for a while and narrowed down the possibilities for failure to static electricity. It seems that the plastic straw rubbing on the nylon string causes a build-up of static. Rubbing your fingers along the line seems to discharge the line. At least this seems to be the most plausible explanation. It could be an interesting discrepant event to have your students explore.

Tips For The Teacher:

☐ The rubber bands supplied with the airplanes will work fine for a short time but will wear out and need to be replaced. Because it is difficult to find exact replacements, you may wish to use a standard size and have exact replacements readily available. I have found that a #33 band available in most office supply stores is a good substitute. You may wish to discard the original bands that come with the airplanes. To get consistent data, the rubber bands should be replaced frequently.

☐ Taking measurement of the PPS is relatively easy. Measurements can be simplified even further by marking the fishing line in one meter increments so that students need only measure to the nearest mark on the string.

☐ A variety of designs are possible but the one described in this article works consistently. Even small deviations in the design can greatly affect how the device will perform. For example spreading the craft sticks out too wide at the bottom can cause the paper clips to swing into the propeller when it begins to move. Using jumbo (#3) paper clips can cause the device to move only short distances or not at all. These variations can be interesting for students to explore or may in some cases just cause frustration.



Marshmallow Catapults

by Mark R. Malone



Focus

Catapults have been used since ancient times to hurl javelins, darts, rocks, and other missiles. In medieval time they were used to discharge heavy stones and other debris over castle walls and across moats. Large models were mounted on strong wooden platforms. The catapults were pulled back by means of twisting cords or with small winches. Smaller hand held catapults were also used. Catapults are still used today to help launch jet airplanes from the decks of aircraft carriers.

A catapult employs a long elastic arm to hurl objects such as rocks or marshmallows. This is in contrast to a trebuchet which utilizes a counterbalanced arm and a sling. Trebuchets were actually much more sophisticated and could hurl objects the size of a small car a distance of 80 meters or more. In their day both catapults and trebuchets were ominous weapons of destruction. Today the basic mathematical concepts learned from the trajectory of these devices is still used to launch satellites to Jupiter and beyond. The basic principles of trajectory are actually employed in many aspects of life. Sports like football, baseball, and golf informally apply the mathematics of trajectory to successfully

play the game. The simple act of tossing a piece of scrap paper into a wastebasket involves at least a rudimentary kinesthetic understanding of trajectory.

Catapult Trajectory:

Various factors can affect how far an object will be thrown from a catapult. These include: the mass of the object thrown, the strength of the launching arm, the angle from which the object is launched, etc. You may wish to have students identify factors with the potential to affect how far a marshmallow will be hurled by the catapult described here.

Trajectory is the path an object travels from its point of launch until it hits the ground or some other obstacle. Different trajectories (paths) result in objects traveling longer or shorter distances. Generally objects launched at steep angles (e.g. near 0°) expend most of their energy in vertical motion. As a result, the object does not travel far horizontally from the catapult. Objects launched at very low angles (e.g. near 90°) are quickly pulled to the ground by gravity before they have much time for horizontal motion.

Every catapult or other launch device has an optimum angle for launch. This angle is a compromise between a vertical launch (0°) and a horizontal launch (90°). The theoretical angle for optimum launch is around 45° . At the optimum angle the object hurled through the air should travel the greatest distance. Students can determine the optimum angle for the marshmallow catapult. In reality it is seldom right at the ideal of 45° . Quirks of its construction often place it as high as 60° or 70° . The ideal, "textbook" 45° would require much more sophisticated equipment than marshmallows and plastic spoons. However, the trajectory concepts embedded in this activity will give a concrete experience with the concept. They should later be able to apply this experience to real world launching devices such as shooting a rifle, archery, golf, rockets, football, baseball, and even jumping skateboards off ramps.

90 degrees	80 degrees	(75)	70 degrees	(65)	60 degrees	(55)	50 degrees
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Construction:

Construction of the marshmallow catapult is quite simple. Cut a piece of furring strip to approximately 1.5 inches (4 cm) in length. *Furring strips are generally .5 x 1.5 x 96 inches (2 cm x 4 cm x 240 cm) long.* Furring strips are long, thin strips of wood that can be purchased at any lumber yard. Assemble the parts as shown. Tape the furring strip piece to the ruler. Tape the ruler to the furring strip piece. Tape a small piece of wooden dowel or stale miniature marshmallow to the spoon as shown.

Copy the angle measuring device pictured below. This should be cut out and taped to a wall or other vertical surface.



the distance the marshmallow flies. Measurements are more accurate if students measure to the spot where the marshmallow first hits the ground. Students working in cooperative groups might assign someone to be a spotter at ground level near where the marshmallow is expected to first hit.

The variable students usually find to be of most interest is varying the angle of launch. This angle can be controlled by taping the angle strip (*below*) to a wall or other vertical surface. The end of the ruler (*catapult*) should be leaned against the angle strip at the appropriate mark. Several trial marshmallows may be launched at the same angles to get an average distance for that angle. Results comparing launches at various angles can be

recorded and compared on the data/graphing sheet provided on page 178. Allow students time to interpret their data results and share findings with their peers.

Materials:

Miniature marshmallows (stale)
Plastic spoons
Wooden ruler 12 in (30 cm)
Masking tape
Ball point pen
Measuring tapes
Furring strip pieces
Data sheet (*See pg. 178.*)
Angle strip (*included below*)

Procedures:

Have students investigate the variables that could affect how far a marshmallow will travel when launched from a catapult. Some free exploration gives students an opportunity to determine what variables might be explored and which must be held constant during their investigation.

To launch marshmallows consistently students should place them on the spoon just beyond the stale marshmallow taped to it. The spoon is pulled back and the marshmallow, when released, will fly through the air. Students should measure

Tips For Teachers:

☐ The data/graphing sheet provided on page 178 is an excellent tool for this activity and a good generic device for reinforcing the skills of graphing in other activities. You may wish to copy the page for use with this and other activities involving data gathering and graphing.

☐ To assure that all marshmallows launch consistently, it is helpful to use the point of a ball point pen to hold back the spoon for launching.. If students use their fingers to release the spoon, the results are often inconsistent.

Reference:

Chevedden P.R., Eigenbrod L., Foley V. & Soedel W. (1995) The trebuchet. *Scientific American*, (273)1, pp 66-71.

(35)	30 degrees	(25)	20 degrees	(15)	10 degrees	(5)	0 degrees
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Name(s) _____

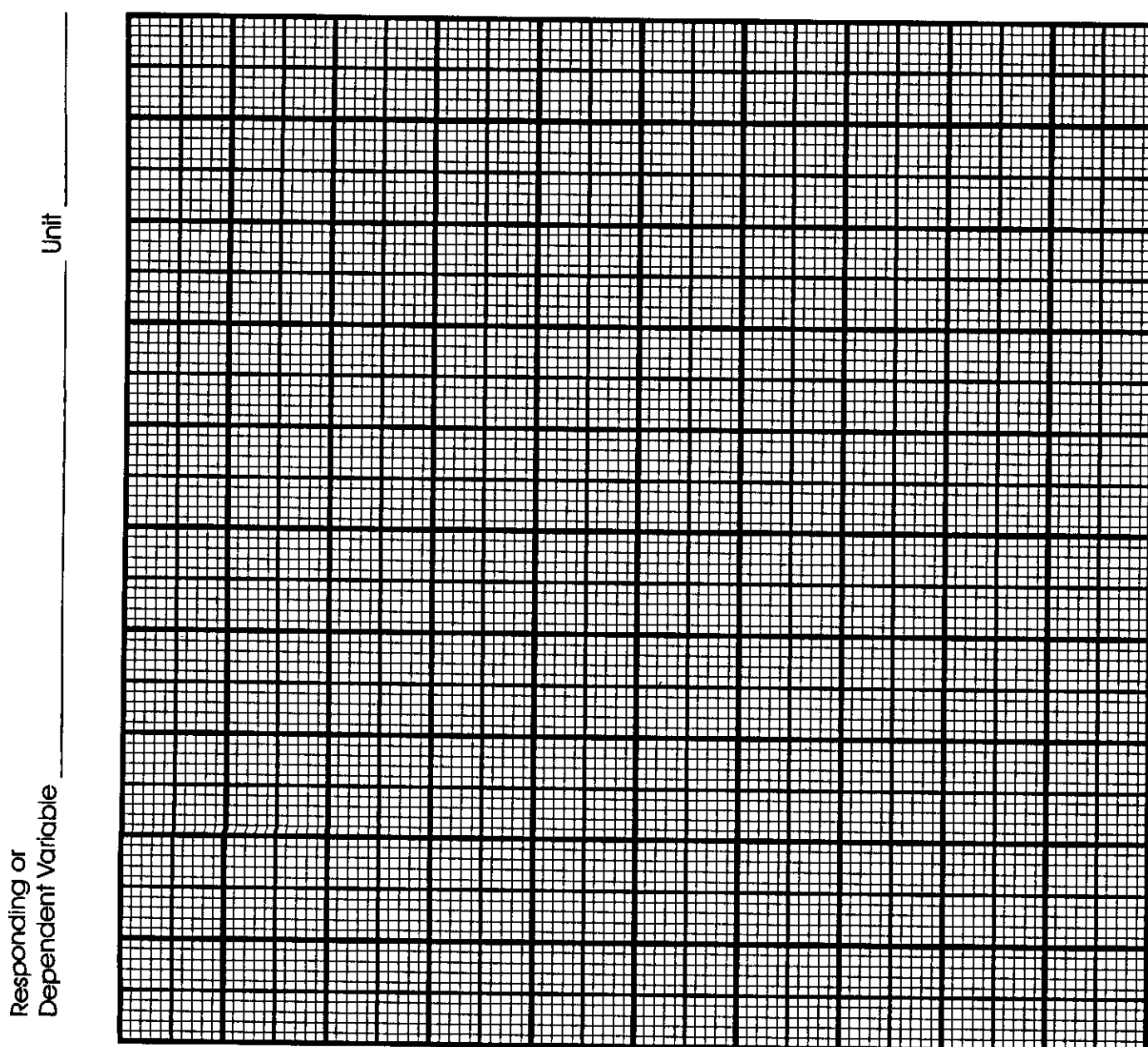
Date _____

Trial 1	Trial 2	Trial 3	Average

Trial 1	Trial 2	Trial 3	Average

y

Title of Graph _____



x

Manipulative or Independent Variable _____ Unit _____

Exploring Atomic Structure

Dave A. Adams and Mark R. Malone

Purpose:

The purpose of this activity is to help students gain a better understanding of how scientists have been able to learn so much about an object that they can not see or touch. This activity will help to develop scientific investigation and inference skills

Long before the tunneling scanning electron microscope or super colliders, Ernest Rutherford discovered the atom had a nucleus. He could not see an atom but, through experimentation he was able to theorize that a nucleus existed at the center of the atom. You may wish to have students look up information on Rutherford's experiments in an encyclopedia or in the school library.

Challenge:

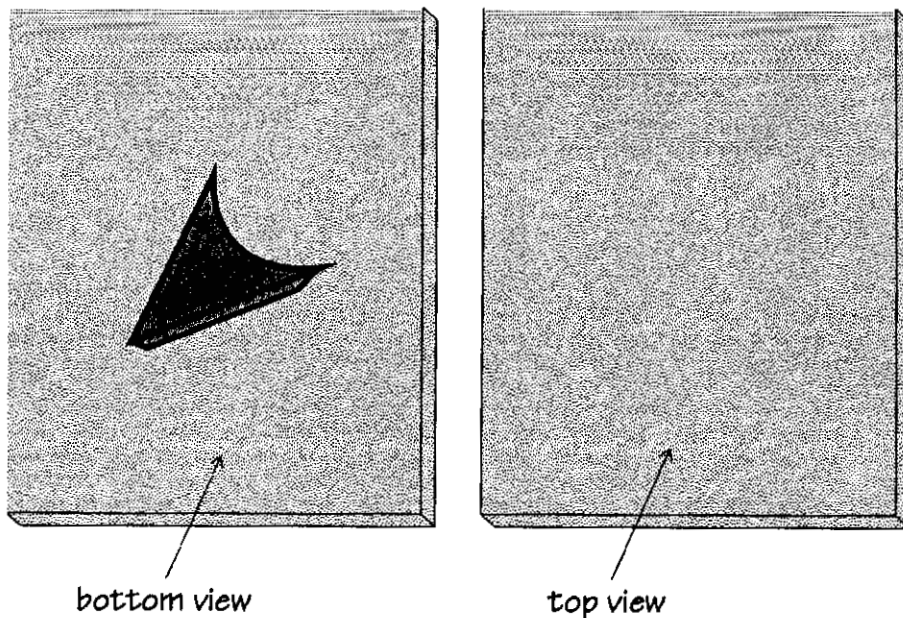
Observe the path of a marble rolled under a piece of cardboard and correctly predict the shape and size of the block of wood attached to the bottom.

Materials:

- Cardboard (8" x 10" with a block of wood glued to it (as shown). The blocks of wood should be of some geometric shape (i.e. triangle, square, octagon, circle...)
- Marbles - one per student and small enough to fit between the block of wood and cardboard when placed block side down on a flat surface.
- Typing paper
- Pencils
- Masking tape

Procedures:

Place the pieces of cardboard on a flat surface block side down prior to students entering the room. You should have one cardboard/block setup for each group of three or four students. Instruct students not to lift up the cardboard. Tell them that they will be determining the shape and size of a block of wood through indirect observation.

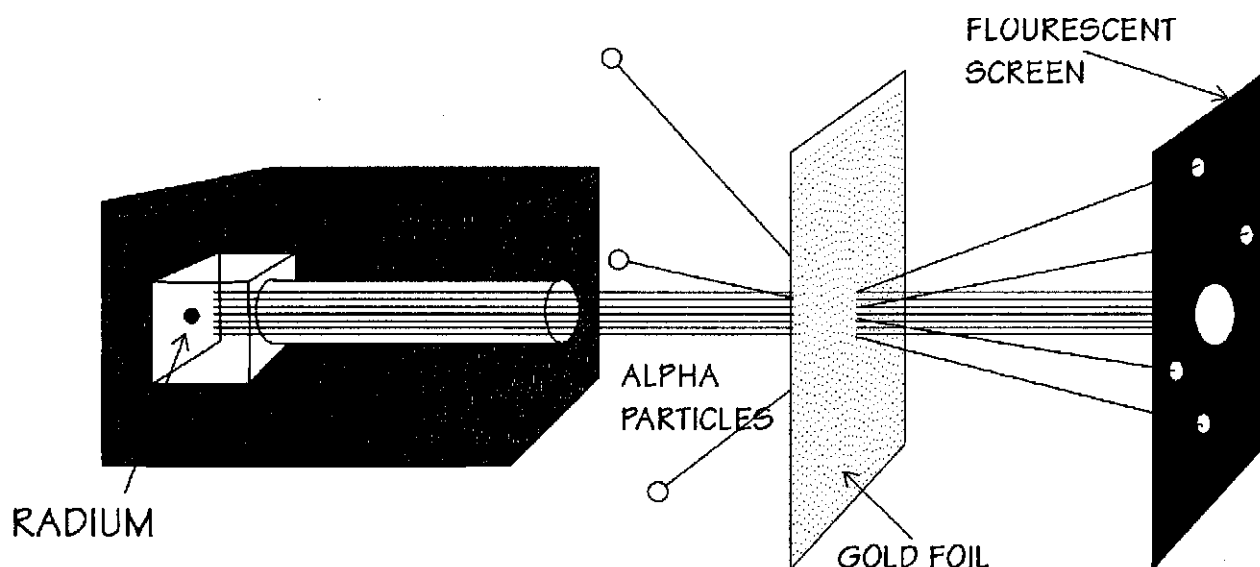


Give each student a piece of blank typing paper and a marble. The paper may be taped to the top of the cardboard to provide a clean writing surface. Instruct students to roll a marble under the cardboard from all directions and then draw the apparent path of the marble on the paper with each trial. Eventually they will discover they have drawn a geometric shape corresponding to the size and shape of the block.

Students are often in a hurry to look at the under side of the cardboard. Remind them to be patient and make careful observations. When they think they know the shape, have them show a partner before they look themselves. If the model they have predicted is not close to the actual shape and size, you may suggest they roll more marbles as additional trials. When they have made an appropriate model, you may wish to have them try an additional shape.

Further Challenges:

- How does this activity relate to atomic structure and the experiments carried out by Rutherford?
- What did you learn about the concept of "theory" by doing this activity?



Rutherford's Experiment Explained:

Ernest Rutherford won a Nobel Prize for physics in 1908 for his discovery of the structure of the atom. With a single experiment, his famous "gold leaf" experiment, he overthrew the previous theory of atomic structure. This experiment involved using alpha particles as bullets to bombard the atomic structure of elements. By today's standards of super conducting super colliders, Rutherford's gun was primitive. It consisted of a thick walled tube with a bit of radium at the bottom. Alpha particles escaped through its opening at approximately one twentieth the speed of light. The energy of these bullets was strong but the results were quite unexpected. At the time of the discovery Rutherford said:

"I remember Geiger coming to me in great excitement and saying, 'We have been able to get some of the alpha particles coming backwards.' It was quite the most incredible event that has ever happened in my life. It was almost as incredible as if you had fired a 15-inch shell at a piece of tissue paper and it came back and hit you. On consideration, I realized that this scattering backwards must be the result of

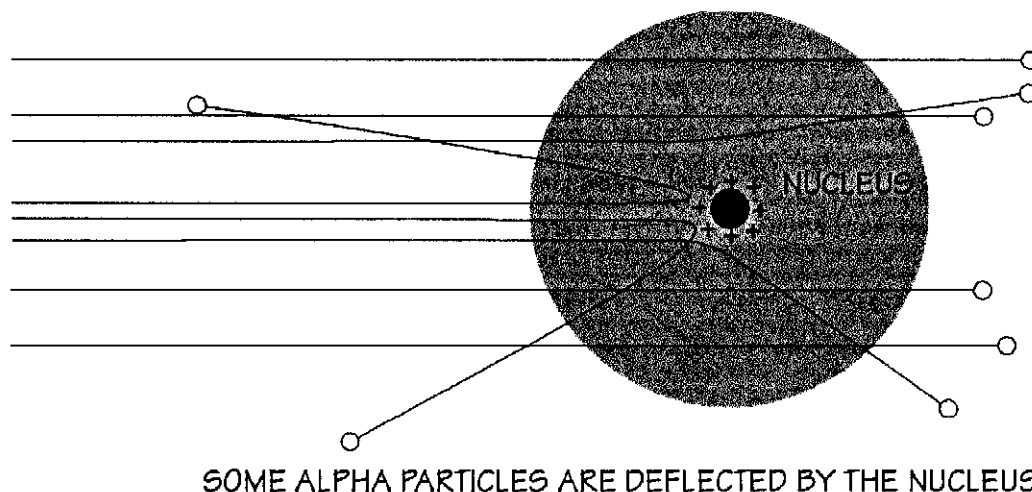
a single collision, and when I made calculations I saw that it was impossible to get anything of that order of magnitude unless you took a system in which the greater part of the mass of the atom was concentrated in a minute nucleus. It was then that I had the idea of an atom with a minute massive center carrying a charge..."

The illustration shows how a thin sheet of gold foil (.0005 inches thick) was bombarded with alpha particles. Rutherford had expected that all of the energetic alpha particles would go through the gold sheet. Most did go straight through. Surprisingly, some were deflected in all directions. Even more surprising some bounced straight back.

This experiment indicated for the first time that atoms are mostly empty space. The occasional particle being reflected back indicated that the centers (*nuclei*) of atoms are highly concentrated and positively charged.

References:

Andrade, E.N. (1964) *Rutherford and the nature of the atom*, Anchor paperback, Garden City, NY, Ch.. 5-6.



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